Environmental Monitoring Report for the Point Lepreau, N.B., Nuclear Generating Station - 1983

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June 1985

Canadian Technical Report of Hydrography and Ocean Sciences No. 59

Canada

85-5822/

Canadian Technical Report of Hydrography and Ocean Sciences

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Cat. No. FS 97-18/59E ISSN 0711-6764

Correct citation for this publication:

Nelson, R.W.P., Ellis, K. and Smith, J.N. 1985. Environmental monitoring report for the Point Lepreau, N.B., nuclear generating station - 1983. Can. Tech. Rep. Hydrogr. Ocean Sci. 59: v + 146 p.

ABSTRACT

Nelson, R.W.P., Ellis, K. and Smith, J.N. 1985. Environmental monitoring report for the Point Lepreau, N.B., nuclear generating station - 1983. Can. Tech. Rep. Hydrogr. Ocean Sci. 59: v + 146 p.

The Point Lepreau Environmental Monitoring Program (PLEMP) has been established within the Department of Fisheries and Oceans to assess the environmental impact of radioactive, thermal, and chemical releases from the Point Lepreau, N.B., Nuclear Generating Station located on the Bay of Fundy. The initial results of the operational phase of the program, for January 1983, when the reactor was operating at 75% of full power, to December 1983, when the reactor was operating at full power for eight months, are presented in this report. During the initial year of the operational program special emphasis was placed on those areas where effects would most likely be observed immediately. Studies were undertaken to characterize the thermal plume produced by the discharge of waste heat to the Bay of Fundy, and included a planned tritium release experiment. Attention was given to tritium levels at the outfall, tritium in the atmosphere, and radionuclide levels in lichen, an efficient accumulator of atmospheric particulates. In addition, radionuclide measurements were made on samples collected during the operational phase from the major environmental reservoirs and these radioactivity levels were compared to those measured during the pre-operational phase to determine any environmental effects associated with the operation of the reactor. The purpose of this program is to provide government with a comprehensive scientific basis upon which to assess the environmental implications of the operation of nuclear reactors in coastal regions.

RÉSUMÉ

Nelson, R.W.P., Ellis, K. and Smith, J.N. 1985. Environmental monitoring report for the Point Lepreau, N.B., nuclear generating station - 1983. Can. Tech 1983. Can. Tech. Rep. Hydrogr. Ocean Sci. 59: v + 146 p.

On a crée, au sein du ministère des Pêches et Océans, le Programme de surveillance écologique de Pointe Lepreau afin d'évaluer les répercussions environnementales des rejets radioactifs, thermiques et chimiques par la centrale nucléaire de Pointe Lepreau située sur la baie de Fundy (Nouveau-Brunswick). On présente les premiers résultats de la phase du programme suivant la mise en exploitation, soit de janvier 1983, lorsque le réacteur était exploité à 75% de son plein régime, jusqu'à décembre 1983, lorsqu'il était exploité à plein régime depuis huit mois. Au cours de la première année de la phase suivant la mise en exploitation, on s'est intéressé de façon toute particulière aux domaines où les effets étaient le plus susceptibles de se manifester immédiatement. On a entrepris des études pour caractériser le panache produit par les rejets thermiques dans la baie de Fundy; ces études comportaient aussi des rejets expérimentaux de tritium. Plus particulièrement, on s'est intéressé aux concentrations de tritium au point d'évacuation, à la presence de tritium dans l'atmosphère et aux concentrations de tritium dans les lichens, car ces organismes accumulent efficacement les particules en suspension dans l'atmosphère. De plus, durant la phase suivant la mise en exploitation on a mesuré la

concentration de radionucléides dans des échantillons prélevés dans les principaux réservoirs environnementaux, et on a comparé ces concentrations avec celles mesurées durant la phase précédant la mise en service, en vue de documenter tout effet associé à l'exploitation du réacteur. Le but de ce programme est de fournir au gouvernement une solide base de données scientifiques à partir de laquelle on pourra évaluer les effets de l'exploitation de réacteurs nucléaires sur l'écologie des régions côtières.

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1.0 INTRODUCTION

The Point Lepreau Nuclear Generating Station (NGS) located at Point Lepreau, N.B. on the Bay of Fundy (Figure 1) houses a 660 MW CANDU reactor making it the first nuclear reactor to go into operation on the Canadian coastline. Table 1 lists some of the key operating events that have occurred at the station since it attained criticality in July 1982. Seawater from the Bay of Fundy is used for cooling water and is discharged back into the Bay of Fundy at elevated temperatures. In addition, radioactive, thermal and chemical releases are discharged principally into the marine environment. The speciation and physico-chemical partitioning of radionuclides released into marine systems can differ from those of radionuclides entering freshwater systems and may present potential problems not previously encountered in the Canadian nuclear power experience. In response to the unique environmental contraints posed by the proximity of this reactor to the ocean, the Point Lepreau Environmental Monitoring Program (PLEMP) has been established within the Department of Fisheries and Oceans to assess the long term environmental impact of the Point Lepreau NGS.

In contrast to most environmental monitoring programs for nuclear reactors which have been primarily concerned with the impact of radioactivity releases on human health, PLEMP has been designed to provide a broader understanding of the distribution of radioactivity throughout the environment. The sampling program has been designed to include the major environmental reservoirs such as seawater, sediments, atmospheric gases and particulates, and marine flora and fauna. Activity measurements made on these samples, combined with the determination of other oceanographic and ecological parameters, are being used to identify transport pathways for radionuclides through environmental phases and to determine fluxes of

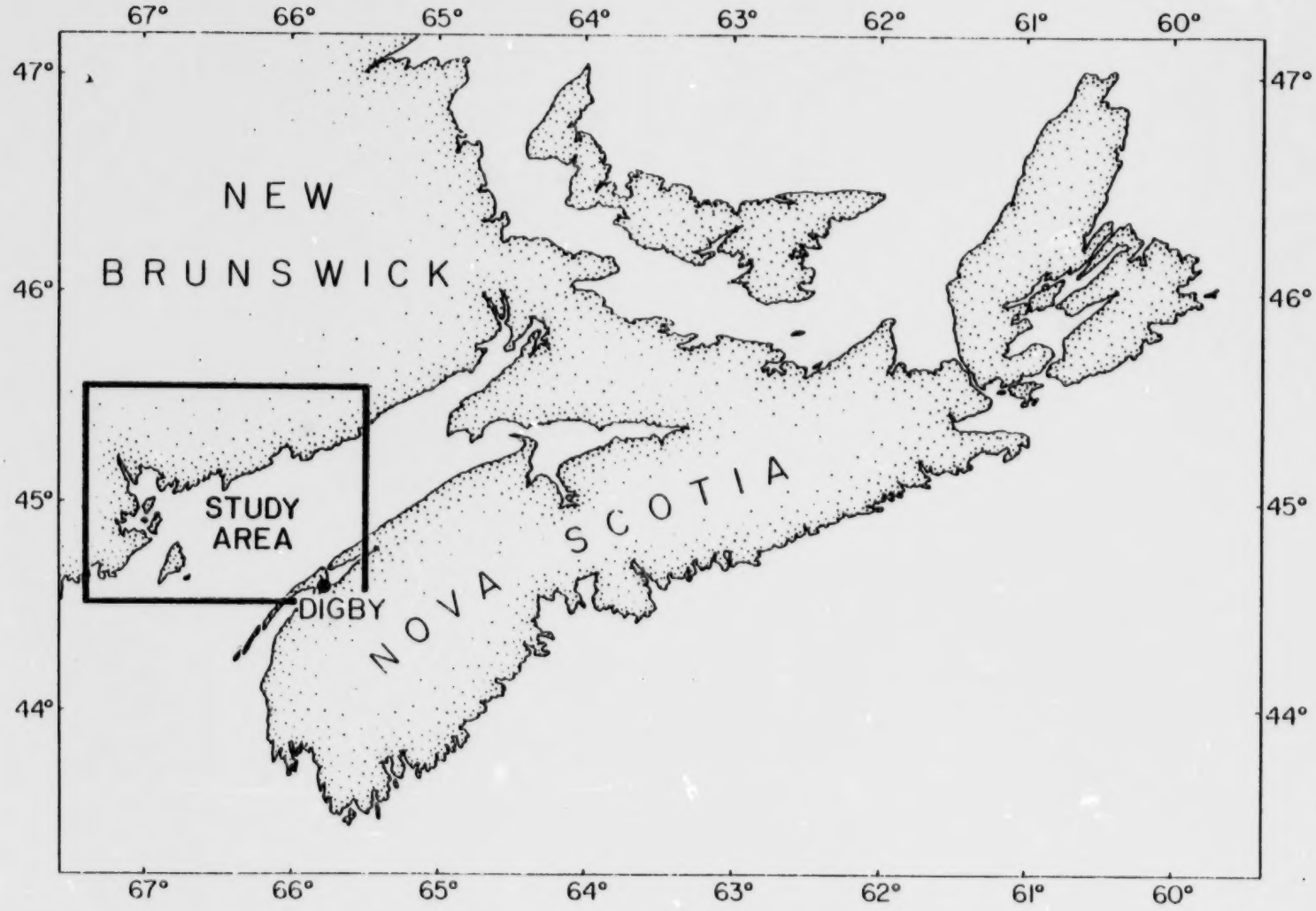

Figure 1. Location of the Point Lepreau study area in the Bay of Fundy.

Table 1. Key events at the Point Lepreau Nuclear Generating Station from criticality to 100% full power.

July	25, 1982	- criticality
August	25, 1982	- 50% full power
September	11, 1982	- first electricity produced for internal use
October	16, 1982	- 25% full power, electricity produced for provincial grid
November	21, 1982	- 50% full power
December	1, 1982	- 65% full power
December	4-9, 1982	- outage
December	11, 1982	- back to 65% full power
December	30, 1982	- 75% full power
January	12, 1983	- 85% full power
February	1, 1983	- 90% full power
March	21-26, 1983	- outage
March	27, 1983	- 100% full power
April 28 - May	2, 1983	- outage
May	3, 1983	- back to 100% full power
May 16 - June	2, 1983	- outage
June	5, 1983	- back to 100% full power

radionuclides along specific pathways.

The responsibility for maintaining PLEMP has been assigned to the Atlantic Environmental Radioactivity Unit (AERU) which is a section of the Chemical Oceanography Division of the Atlantic Oceanographic Laboratory, Department of Fisheries and Oceans located at Bedford Institute of Oceanography, Dartmouth, Nova Scotia. In addition, a working group on environmental radioactivity, composed of scientists in various disciplines and departments in the Atlantic region (Appendix 1), has been established to ensure that the concerns and responsibilities of different agencies with respect to Point Lepreau are addressed in a coordinated manner by PLEMP. The working group advises AERU on field activities, reviews reports produced during this program and members of the working group act as scientific authorities for contracts administered by AERU.

The monitoring program was divided into a pre-operational and an operational phase. The pre-operational phase of PLEMP began in 1979 and was completed in 1982 when the reactor became operational. During the pre-operational phase of PLEMP, baseline radioactivity and chemical measurements were performed to characterize the natural and fallout radioactivity background in the vicinity of Point Lepreau as well as the predominate transport processes of the area. Pre-operational data is summarized in Bishop et al. (1980), Smith et al. (1981, 1982) and Ellis et al. (1984).

The operational phase of PLEMP began in 1983 with the ultimate goal of providing government with a sound scientific basis upon which to assess the environmental implications of the operation of nuclear reactors in coastal environments. Results presented in this report provide PLEMP's first data for the operational phase of the Point Lepreau NGS. The major emphasis for the first year of the monitoring program was in areas where

effects would most likely be observed immediately. Of particular interest was the thermal plume produced in the Bay of Fundy as a result of the discharge of waste heat from the cooling water tritium levels at the reactor outfall and in atmospheric samples and radionuclide levels in lichen, the latter being a well known accumulator of atmospheric particulate material. In addition, radionuclide measurements have been made for samples collected from the major environmental reservoirs and levels compared with those found during the pre-operational phase in order to document any environmental effects associated with the operation of the reactor.

This report, the fifth in a series of annual monitoring reports for the Point Lepreau NGS, describes work conducted during 1983 and constitutes the first report covering the operational phase of the PLEMP program.

2.0 MARINE ENVIRONMENT

2.1 Water Circulation

Water circulation patterns in the Bay of Fundy are dominated by a cyclonic, anti-clockwise gyre with inflow along the coast of Nova Scotia and outflow along the New Brunswick coast passing to the east of Grand Manan Island (Bumpus et al., 1965). Water movement in the Bay of Fundy is characteristic of simple estuarine circulation. Low salinity water dominated by inputs from the Saint John River, (from which up to 60% of the freshwater input originates), flows out at the surface, while denser shelf and slope water mixes across the shelf break and enters the Bay of Fundy at depths predominantly below 100 metres. Salinity-depth profiles have been constructed along three transects as in previous reports, from data collected April 12-18 1983, during cruise 83-003 (Figure 2) to illustrate the predominant characteristics of water circulation in the Point Lepreau area.

The three transects, illustrated in Figure 2, were chosen to approximate those examined during earlier cruises. The profiles for cruise 83-003 are typical of previous spring cruises (Ellis et al., 1984). Transect B, Figure 3, illustrates the influence of the freshwater plume along the New Brunswick coast and confirms the minimal mixing which occurs between the freshwater plume and higher salinity bottom water occurs. Transect C, Figure 4, shows the extent to which the freshwater plume remains close to the New Brunswick coast, with influence extending no more than 20 kilometers offshore. Transect A, Figure 5, illustrates a cross-section of the freshwater plume as it splits around Grand Manan Island. It appears that the major portion of the freshwater plume stays close to the coastline and moves west of Grand Manan Island. This differs from patterns observed during the 1981 cruise, 81-010, where the major portion of the

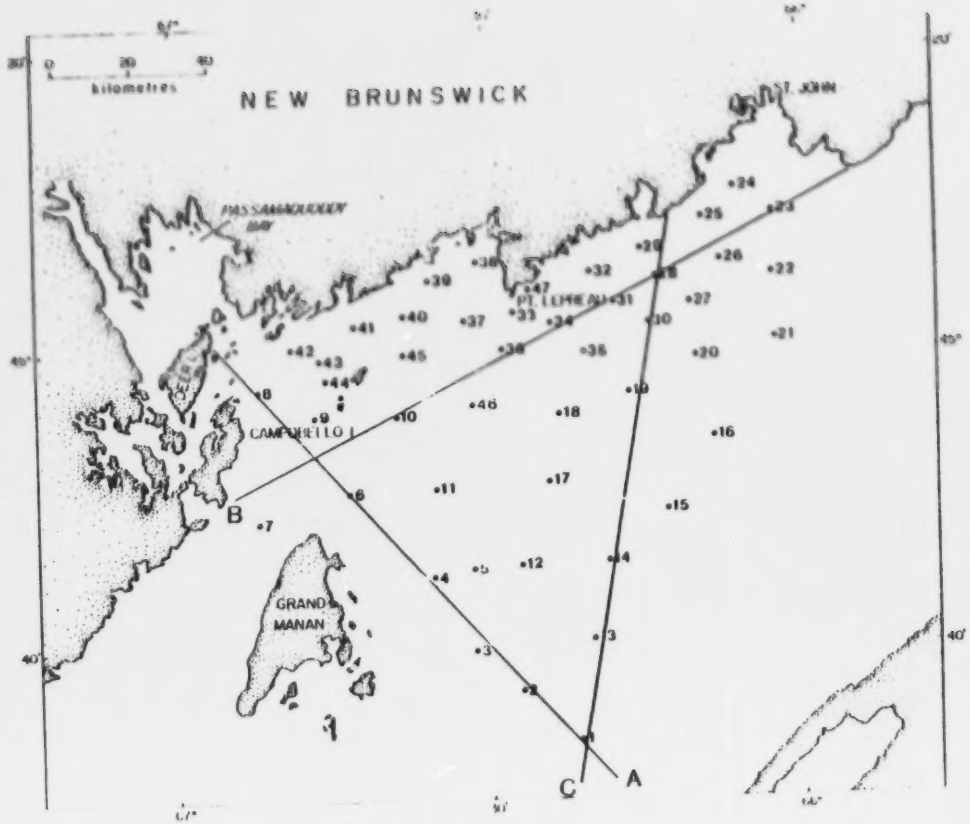

Figure 2. Station locations for Cruise 83-003 and transect lines used for salinity depth profiles shown in figures 3, 4, and 5.

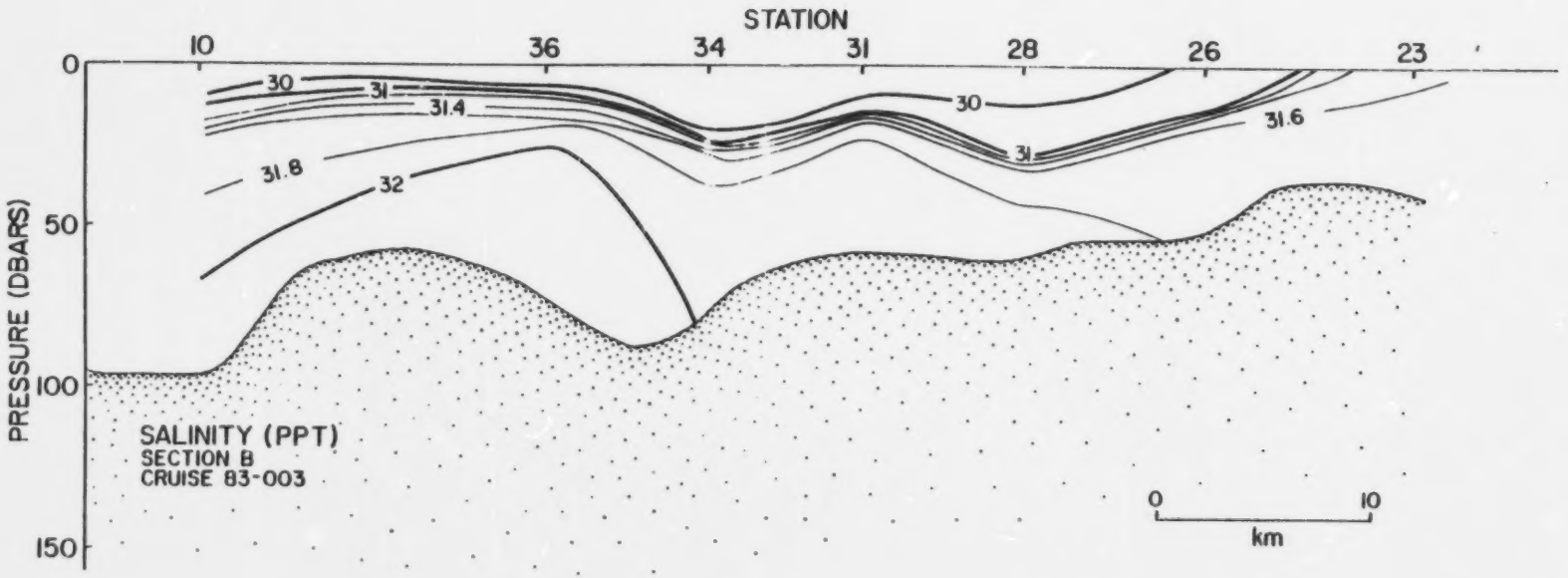

Figure 3. Salinity depth profile for transect B, shown in Figure 2.

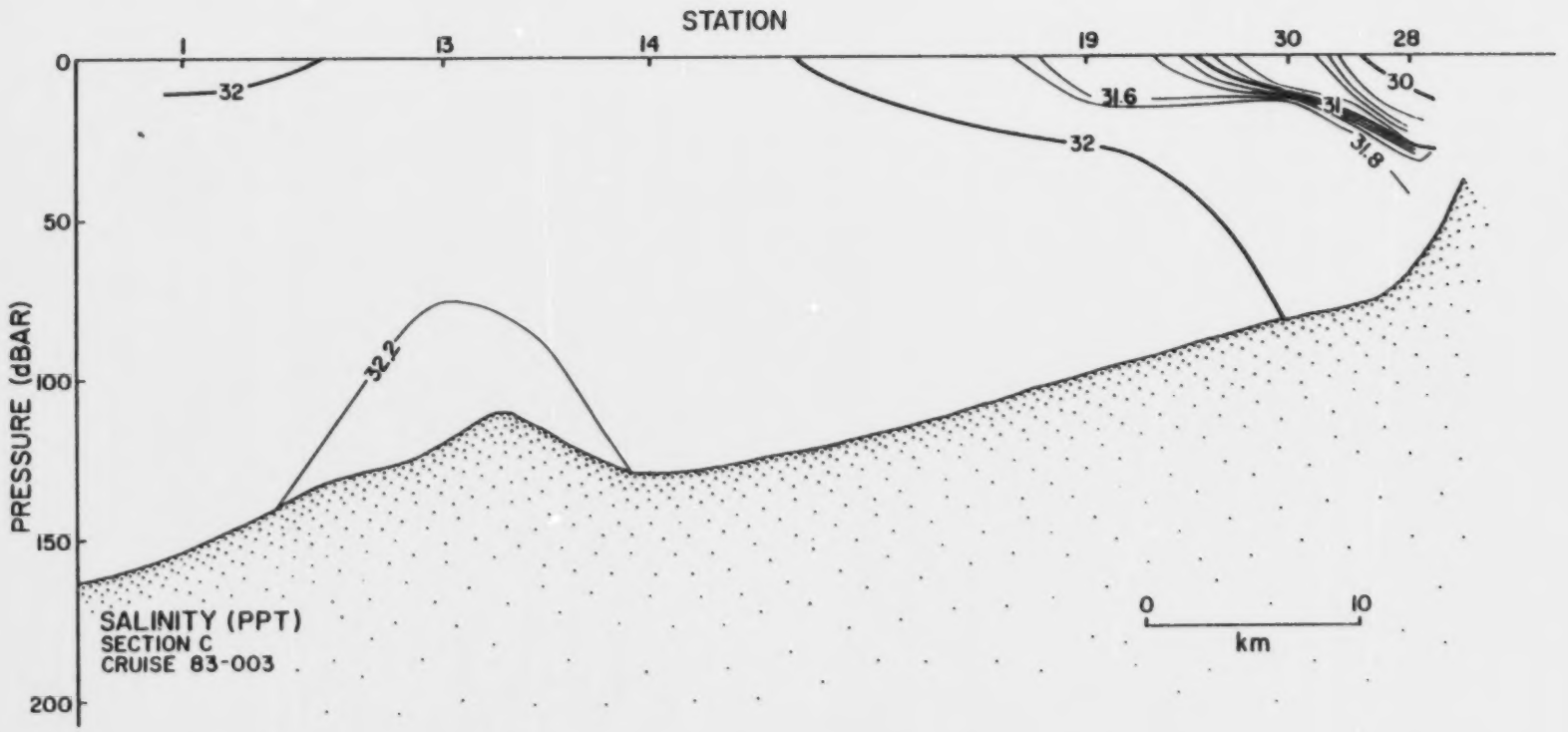

Figure 4. Salinity depth profile for transect C, shown in Figure 2.

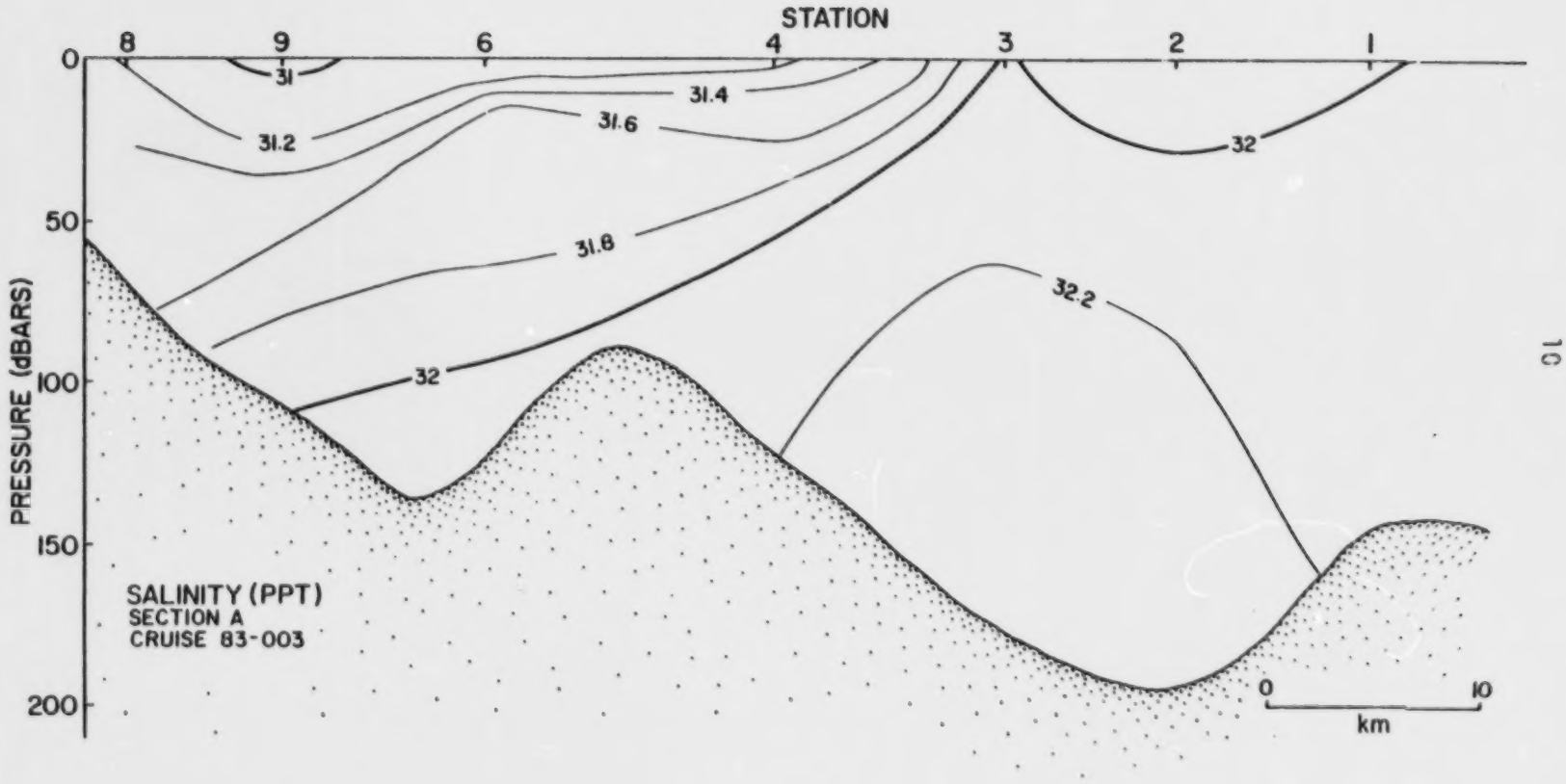

Figure 5. Salinity depth profile for transect A, shown in Figure 2.

freshwater plume appeared to flow to the southeast of Grand Manan Island. The results of a surface drifter program conducted by G. Bugden (1980, 1985) indicate that surface currents in the Bay of Fundy tend to move along the New Brunswick coastline and that the major impact area for surface drifters released from Point Lepreau was the Passamaquoddy Bay region (Bugden, 1985).

In general, water circulation patterns in the Bay of Fundy indicate that the spring is a time of increased stratification and reduced vertical mixing. The major portion of the freshwater plume originates from the Saint John River and travels down the New Brunswick coastline extending offshore approximately 20 km and then splits around Grand Manan Island. Vertical transport of contaminants will be reduced but their horizontal transport and impingement on the coastal intertidal zone may be enhanced.

2.2 Effluent Releases

The release of radioactive materials to the environment is an inevitable consequence of the use of nuclear energy. The operation of nuclear power plants results in the generation of gaseous and liquid radioactive wastes. The radioactivity in these wastes must be reduced before release to the environment can be considered. The treatment of radioactive effluent can range from short-term storage, to dilution, to containment and storage.

There are three main sources of radioactive wastes: fission products released from the fuel matrix into the primary coolant; neutron activation of deuterium in the heavy water thereby creating tritium and neutron activation of reactor support and encasement material, creating activation products.

Emissions from the Point Lepreau NGS are closely monitored at the source by the Liquid Effluent Monitoring Program (LEM) conducted by the New Brunswick Electric Power Commission (NBEPC). The liquid effluent monthly summary from the Point Lepreau NGS is presented in Table 2. Releases are reported as a percent of the Derived Emission Limit (DEL) that has been estimated for each radionuclide and as expected, emission rates are well below the DEL. The LEM program provides for the proper characterization of liquid effluent releases, which in turn can provide detailed information to aid in the determination of concentration factors, critical pathways and radionuclide migration.

2.3 Chemical Oceanography

Radionuclides discharged into the ocean by the nuclear industry are generally point source releases into coastal waters. Releases may be in the form of primary or secondary cooling waters, treated low level wastes, or accidental discharges (cooling water spills, ruptured fuel elements etc.). Speciation plays an important role in the fate of artificial radionuclides released from various sources into the oceans. Radionuclides discharged from nuclear generating stations often enter the oceans in different chemical forms from those of their stable analogues present in the receiving waters. If the attainment of equilibrium is slow, radionuclides and their stable analogues in the marine biosphere may exhibit significant behavioral differences. In addition, chemical forms and equilibrium situations may be different in biologically-active coastal water as compared to 'clean' open ocean water.

The chemical oceanography section of PLEMP was designed to help characterize the general water column chemistry of the western Bay of Fundy

Table 2. Liquid effluent monthly summary for 1983 from Point Lepreau Nuclear Generating Station.

Nuclide	Monthly DEL Bq	% Monthly DEL Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Bq Released	Avg. % DEL
H-3	4×10^{18}	2×10^{-6}	5×10^{-6}	9×10^{-6}	7×10^{-5}	2×10^{-5}	3×10^{-5}	2×10^{-5}	4×10^{-5}	3×10^{-5}	3×10^{-5}	2×10^{-5}	1×10^{-5}	9.1×10^{12}	1.9×10^{-5}
Cr-51	2×10^{15}	5×10^{-7}	4×10^{-7}	1×10^{-6}	3×10^{-5}	5×10^{-6}	6×10^{-7}	2×10^{-7}	2×10^{-8}	2×10^{-8}	1×10^{-6}	4×10^{-8}	6×10^{-8}	7.7×10^{8}	3.2×10^{-6}
Mn-54	2×10^{13}	-	-	-	-	-	-	-	-	-	1×10^{-6}	-	-	3.4×10^{5}	1.2×10^{-7}
Fe-59	1×10^{13}	-	-	5×10^{-6}	8×10^{-6}	2×10^{-6}	-	-	-	-	2×10^{-5}	-	2×10^{-6}	1.8×10^{7}	1.6×10^{-5}
Co-60	3×10^{13}	-	-	3×10^{-6}	8×10^{-6}	2×10^{-6}	-	-	-	6×10^{-6}	6×10^{-6}	2×10^{-6}	2×10^{-6}	7.5×10^{6}	2.3×10^{-6}
Zr-95	6×10^{13}	3×10^{-7}	-	4×10^{-7}	7×10^{-6}	3×10^{-5}	7×10^{-6}	7×10^{-7}	7×10^{-6}	2×10^{-6}	2×10^{-6}	3×10^{-5}	3×10^{-6}	5.3×10^{7}	7.4×10^{-6}
Nb-95	6×10^{13}	4×10^{-7}	-	8×10^{-7}	9×10^{-7}	4×10^{-5}	1×10^{-5}	2×10^{-6}	1×10^{-5}	6×10^{-6}	1×10^{-5}	4×10^{-5}	5×10^{-6}	8.4×10^{7}	1.2×10^{-5}
Ru-103	1×10^{14}	-	-	-	-	5×10^{-6}	-	-	-	-	-	4×10^{-7}	-	6.1×10^{6}	4.6×10^{-7}
Ag-110M	1×10^{13}	-	-	-	-	-	-	-	-	-	-	2×10^{-6}	-	2.8×10^{5}	1.8×10^{-7}
I-131	1×10^{13}	-	-	-	4×10^{-3}	1×10^{-5}	3×10^{-5}	-	-	-	3×10^{-6}	-	-	2.1×10^{9}	1.4×10^{-3}
Cs-134	4×10^{13}	-	-	-	1×10^{-6}	8×10^{-7}	-	-	-	-	-	-	-	9.1×10^{5}	1.8×10^{-7}
La-140	2×10^{14}	-	-	-	-	4×10^{-7}	-	-	-	-	-	-	-	6.4×10^{5}	3.6×10^{-8}
Ce-141	2×10^{14}	-	-	-	-	2×10^{-7}	9×10^{-8}	-	-	-	-	-	-	7.0×10^{5}	2.5×10^{-8}
Ce-144	2×10^{13}	-	-	-	-	-	-	1×10^{-6}	-	-	-	4×10^{-5}	-	8.0×10^{6}	3.3×10^{-6}

Average emission rate (all nuclides) 1.53×10^{-3} % DEL.

and to establish baseline levels of radionuclides and their stable analogues in order to predict the transport properties of radionuclides released from the Point Lepreau NGS. The operational phase of PLEMP continues to include the measurement of important hydrographic parameters, such as temperature, salinity, nutrients, and suspended particulate matter, and, in addition, monitors the levels of Cs-137, H-3, plutonium, and gamma-emitting radionuclides both in the water column and sediments. The information collected in the post-operational phase of the program can be compared to pre-operational data to assess any post-operational releases of radioactivity that may take place. In addition, information on water circulation patterns, dispersion rates and particle transport processes in the Point Lepreau region is being continually updated.

2.3.1 Radionuclides - Water Column

The April 1983 cruise, 83-003, was the first post-operational cruise conducted by AERU. The seawater sampling procedures and the analytical methods used at the AERU laboratory have been described previously (Ellis et al., 1984). Briefly, 50 litre water samples were collected at surface and bottom water depths and the seawater samples were passed through columns consisting of: (1) a 0.3 micrometre pore size filter to remove particulates; (2) chelex-100 ion exchange resin to adsorb activation products, such as Co-60 and Mn-54; and (3) a KCFC column (potassium cobalt ferrocyanide) that absorbs Cs-137 (Figure 6). Samples were also collected and analyzed for nutrients, salinity and tritium. In addition, the first thermal plume studies were undertaken to determine the effects, if any, of thermal releases from the Point Lepreau NGS. The sampling matrices and nuclear instrumentation used in this program are summarized in Table 3.

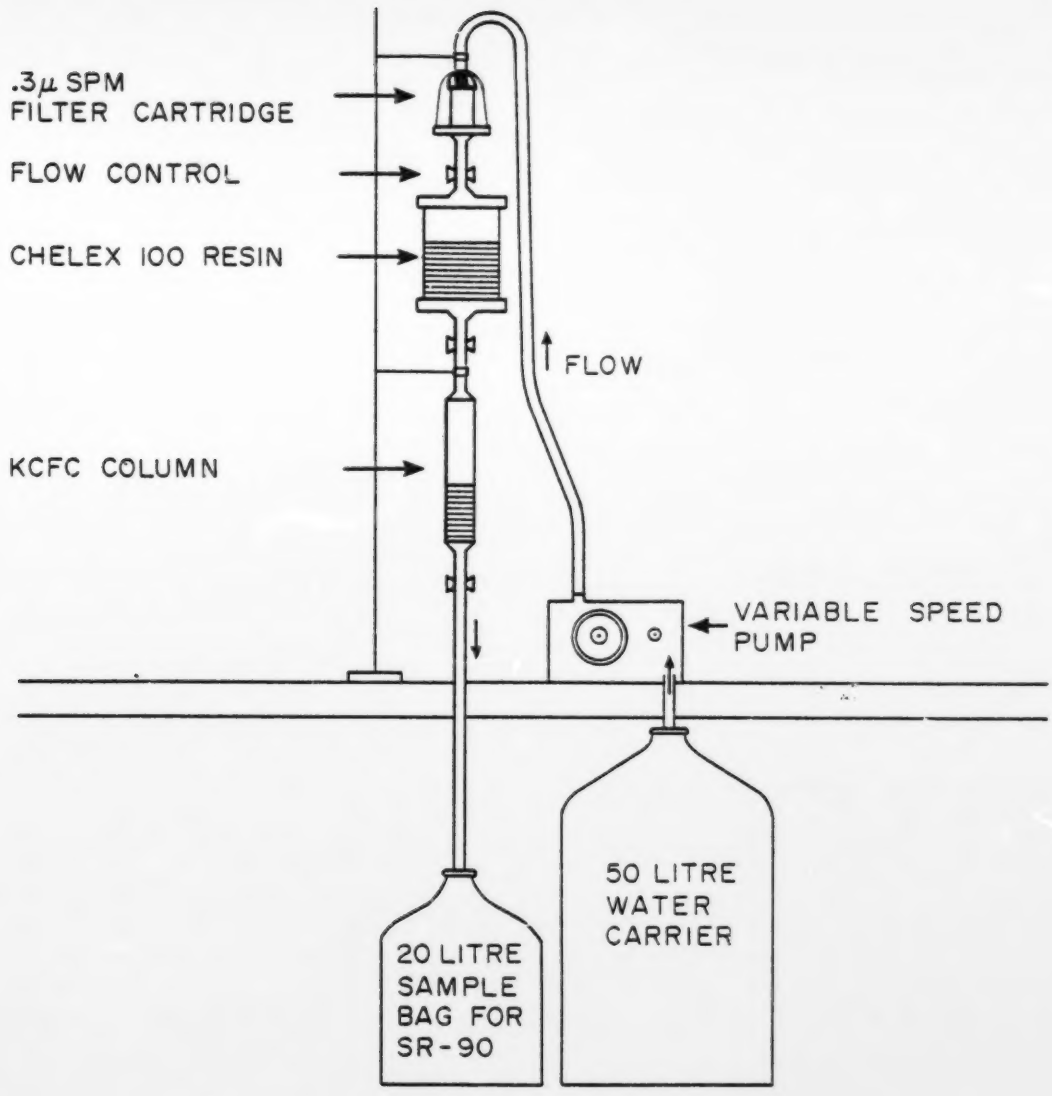

Figure 6. Schematic diagram of column used to concentrate radionuclides from seawater.

Table 3. Summary of nuclear instrumentation used in the AERU Laboratory.

Nuclide	Environmental Phase	Counting Matrix	Detection System
Cs-137	Seawater	KCFC	Geli and NaI Detectors
Cs-137	SPM	Filter Cartridge (0.3 μm)	Geli Detector
Cs-137	Sediment	Dried Bulk Sediment	Geli and NaI Detectors
Sr-90	Seawater, SPM, and Sediment	Y-90 on Filter Paper	Alpha/Beta Counter
Gamma Emitters	Seawater	Chelex-100 Eluate	Geli Detector
Gamma Emitters	SPM	Filter Cartridge (0.3 μm)	Geli Detector
H-3	Seawater	Gel (Water/Cocktail)	Liquid Scintillation Counter
Pb-210 (Po-210)	SPM, Sediments	Ag,Ni Discs	Alpha Spectrometer (Surface Barrier Detectors)
Pu-239,240	Sediment	Steel Disc	Alpha Spectrometer
Ra-226	Sediment	Ra-222 Gas	Gas Phase Scintillation Counter
Ra-226	Sediment	Bi-214 in Dried Bulk Sediment	Geli Detector

2.3.1.1 Cs-137 Activity in Seawater

Cs-137 is a relatively long-lived ($t_{1/2}$ = 30 years) fission product which is rapidly and efficiently incorporated into the marine biosphere. Because of its long residence time in the ocean and its biological importance, it is among the most environmentally hazardous radionuclides entering marine systems. In addition, it is one of the few fission products that will be released from the NGS that is present in readily detectable quantities in the ocean today.

The Cs-137 results for sea water samples collected during the spring 1983 cruise, 83-003, are presented in Table 4. Radioactivity measurements are reported in units of Becquerels (Bq) which is defined as a disintegration per second. Conversion factors for commonly used radioactivity units are listed in Appendix 2. The mean Cs-137 activity in sea water for all stations excluding the anchor station was 3.29 ±0.58 mBq/l with a range of 2.45 to 4.76 mBq/l. These are similar to pre-operational Cs-137 levels found in the Bay of Fundy during spring cruises in 1979 and 1981 (Table 5). As noted on previous cruises, there was no strong correlation between Cs-137 activity and either water depth or geographical location, an observation that is indicative of the efficient tidal mixing in the Bay of Fundy. In contrast to the two cruises undertaken in 1979, where a weak (r=0.55, n=80) inverse correlation between salinity and Cs-137 activity was found, no significant correlation was found between salinity and Cs-137 levels during the 83-003 cruise. This agrees with results from the June 1980 (80-018) and the April 1981 (81-010) cruises (Ellis et al., 1984). Suspended particulate matter (SPM) concentrations were measured at surface and bottom water depths at selected stations. The bottom water SPM concentrations were slightly higher than surface water (average 8.64 mg/l

Table 4. Cs-137, H-3, SPM and Nutrient Results for Selected Stations Sampled During Cruise 83-003.

Sample Ident.	Station	Depth m	Salinity 0/00	Temp °C	Silicate UG-AT/L	Phosphate UG-AT/L	Nitrate UG-AT/L	SPM mg/l	Cs-137 mBq/l	Tritium Bq/l
83-06401	1	167	32.200	3.80	6.99	0.64	7.62	1.09	2.67 ± 0.47	<1.6
83-06402	1	0	32.009	4.08	6.71	0.82	7.81	0.26	3.30 ± 0.57	
83-06405	3	172	32.230	3.60	7.26	0.83	8.18	8.65	3.85 ± 0.57	
83-06406	3	0	32.060	4.05	6.23	0.60	6.92	0.33	4.32 ± 0.32	
83-06414	6	125	32.195	3.57	6.41	0.61	7.26	1.45	3.55 ± 0.50	
83-06415	6	0	30.777	3.78	8.79	0.62	8.20	0.96	2.83 ± 0.35	
83-06418	7	91	31.822	3.35	7.88	0.68	8.30	-	-	<1.6
83-06419	7	0	31.412	3.55	7.94	0.62	7.88	-	-	<1.6
83-06420	8	91	31.575	3.41	8.33	0.66	8.17	10.60	3.23 ± 0.53	
83-06421	8	0	31.216	3.51	7.68	0.60	7.33	1.04	3.03 ± 0.53	
83-06426	11	108	32.107	3.56	5.90	0.64	6.67	2.02	3.45 ± 0.68	
83-06427	11	0	29.654	4.21	9.75	0.62	8.14	1.56	3.48 ± 0.52	
83-06432	14	129	32.153	3.73	6.70	0.66	7.44	2.51	4.27 ± 0.53	
83-06433	14	0	32.084	4.22	6.54	0.62	7.06	0.32	3.77 ± 0.37	
83-06438	17	120	32.161	3.67	6.78	0.72	7.72	0.73	2.87 ± 0.48	<1.6
83-06439	17	0	32.096	4.07	6.01	0.58	6.66	13.10	2.63 ± 0.53	<1.6
83-06449	22	64	31.802	2.38	8.39	0.66	9.26	13.00	3.18 ± 0.52	1.6 ± 1.6
83-06450	22	1	31.674	2.36	8.23	0.62	8.74	12.60	4.00 ± 0.63	1.9 ± 1.6
83-06451	24	20	31.544	2.26	8.98	0.82	9.15	-	-	3.4 ± 1.6
83-06454	24	0	29.625	2.41	9.67	0.69	9.49	-	-	3.2 ± 1.6
83-06457	26	49	31.719	2.18	9.16	1.00	9.89	30.20	2.82 ± 0.37	
83-06458	26	0	30.560	2.58	11.01	0.79	9.98	2.63	2.60 ± 0.57	
83-06466	29	36	31.655	2.71	9.17	0.83	9.47	22.70	2.75 ± 0.52	
83-06467	29	1	26.857	2.91	11.58	0.64	8.74	18.80	3.57 ± 0.66	
83-06468	30	76	31.999	3.22	6.55	0.57	7.03	-	-	<1.3
83-06469	30	0	30.760	3.55	6.19	0.50	5.96	-	-	<1.3
83-06473	32	39	31.782	3.02	6.53	0.63	6.70	4.39	3.84 ± 0.43	
83-06474	32	1	27.176	3.26	8.76	0.46	6.14	13.10	2.45 ± 0.70	
83-06482	36	58	32.049	3.43	5.50	0.58	6.21	4.98	3.48 ± 0.48	<1.3
83-06483	36	1	29.583	3.64	9.28	0.54	7.52	11.00	3.07 ± 0.63	<1.3
83-06488	39	26	30.633	3.62	9.83	0.69	8.85	-	-	<1.3
83-06489	39	1	29.856	3.60	10.46	0.60	8.66	-	-	<1.3
83-06492	41	42	31.757	3.17	7.34	0.74	7.93	4.19	3.15 ± 0.48	<1.3
83-06493	41	1	30.800	3.83	9.57	0.72	9.89	11.80	2.80 ± 0.55	<1.3
83-06503	46	71	31.977	3.45	5.27	0.48	5.59	14.30	3.50 ± 0.48	
83-06504	46	0	31.088	3.63	5.84	0.42	5.91	1.60	2.83 ± 0.50	

Table 4. Cs-137 - continued

Sample Ident.	Station	Depth m	Salinity 0/00	Temp °C	Silicate UG-AT/L	Phosphate UG-AT/L	Nitrate UG-AT/L	SPM mg/l	Cs-137 mBq/l	Tritium Bq/l
83-06505	47	37	31.810	3.29	8.18	0.74	8.81	3.69	2.37 ± 0.48	
83-06508	48	0	27.775	3.16	10.36	0.74	10.26	17.20	3.32 ± 0.52	
83-06509	49	39	31.631	3.08	7.62	0.72	8.31	19.80	3.27 ± 0.52	
83-06512	50	0	27.644	3.16	12.25	0.58	9.18	12.40	2.80 ± 0.61	
83-06513	51	35	31.591	3.00	8.66	0.84	8.57	12.90	3.88 ± 0.52	
83-06516	52	1	27.749	3.12	10.99	0.58	8.66	1.72	2.68 ± 0.52	
83-06517	53	32	31.579	3.04	9.08	0.84	9.07	14.90	3.87 ± 0.50	
83-06550	54	0	29.547	3.45	11.35	0.69	9.64	12.80	3.30 ± 0.53	
83-06551	55	36	31.669	3.25	8.04	0.79	8.65	22.30	3.68 ± 0.48	
83-06554	56	0	29.467	3.42	11.16	0.70	9.23	10.50	3.15 ± 0.50	
83-06555	57	38	31.768	3.13	5.96	0.60	6.22	15.20	2.95 ± 0.52	
83-06558	58	1	28.917	3.42	11.82	0.64	8.93	10.40	3.25 ± 0.48	
83-06559	59	37	31.876	3.28	6.04	0.58	6.19	15.20	3.50 ± 0.50	
83-06562	60	0	29.173	3.70	10.54	0.62	7.97	10.90	2.65 ± 0.46	
83-06563	61	35	31.707	3.22	7.83	0.74	7.90	20.60	3.20 ± 0.57	
83-06566	62	1	27.991	3.85	8.56	0.49	6.39	6.80	2.87 ± 0.53	
83-06567	63	33	31.589	2.92	9.26	0.90	8.77	35.60	2.55 ± 0.57	
83-06570	64	1	27.922	3.19	10.55	0.63	8.40	3.19	2.97 ± 0.52	
83-06571	65	31	31.614	2.95	8.83	0.90	9.33	7.12	3.30 ± 0.52	
83-06573	66	31	31.602	3.17	8.95	0.79	8.57	21.00	3.40 ± 0.55	
83-06576	67	1	29.266	3.55	11.28	0.68	9.10	3.25	3.05 ± 0.52	
83-06578	68	0	28.871	3.49	12.38	0.71	9.70	8.74	3.25 ± 0.48	
83-06579	69	40	31.672	3.27	6.77	0.66	6.96	26.80	3.52 ± 0.53	
83-06582	70	0	28.554	3.41	7.93	0.51	6.31	10.10	3.33 ± 0.53	
83-06583	71	41	31.884	3.28	7.24	0.75	7.57	17.00	3.12 ± 0.53	
83-06586	72	0	28.508	3.16	11.09	0.62	9.05	10.90	2.42 ± 0.55	
83-06587	73	41	31.814	3.20	7.87	0.82	8.20	26.10	3.75 ± 0.52	
83-06590	74	0	27.639	3.02	8.22	0.42	6.28	8.28	2.23 ± 0.53	
83-06591	75	33	31.563	2.85	7.72	0.72	7.68	26.00	2.93 ± 0.53	
83-06594	76	1	26.890	3.06	13.53	0.69	10.05	10.90	2.68 ± 0.46	
83-06595	77	30	31.581	2.87	7.81	0.78	7.98	10.80	3.57 ± 0.52	
83-06598	78	1	26.945	3.28	11.88	0.57	8.60	2.50	3.07 ± 0.55	
83-06599	79	38	31.658	3.02	7.60	0.77	7.75	21.20	3.65 ± 0.52	
83-06702	80	1	28.065	-	9.74	0.58	7.59	2.46	3.18 ± 0.53	
83-06704	81	40	31.778	-	5.55	0.64	5.90	6.50	2.70 ± 0.53	
83-06707	82	1	28.599	3.52	9.46	0.57	7.67	10.10	3.10 ± 0.52	

Table 5. Average radionuclide values measured in the water column for all cruises.

Cruise No.	Date	Radionuclide Concentrations Cs-137 (Particulate) mBq/l	Cs-137 (Dissolved) mBq/l	Sr-90 mBq/l	H-3 mBq/l
Pre-operational					
79-007	May 1-6, 1979	-	3.8* ± 0.7**, n=28	3 ± 1,n=13	2700 ± 3000
79-027	Oct 24-28, 1979	-	2.6 ± 0.8 , n=24	-	1700 ± 2700
80-018	Jun 9-14, 1980	< 0.8	4.2 ± 0.3 , n=43	-	< 2300
81-500	Feb 23-26, 1981	< 1.5	4.4 ± 0.5 , n=20	-	2840 ± 1200
81-010	Apr 14-21, 1981	< 1.2	3.5 ± 0.3 , n=33	-	2210 ± 580
Post-Operational					
83-003	Apr 12-18, 1983		3.3 ± 0.6 , n=30	-	2525 ± 910

* Mean radionuclide values calculated using a single mean from the anchor station data.
** Error reported is the statistical error for mean value.

compared to 6.36 mg/l), probably as a result of sediment resuspension phenomena.

Surface and bottom water samples were collected every hour for a 36-hour period at a designated anchor station (Stations 47-84, each cast was represented as a separate station), located several hundred metres off the reactor outfall at Point Lepreau. Surface and bottom water measurements of Cs-137, salinity, SPM, and tidal cycle are illustrated in Figures 7 and 8. Salinities for bottom water samples fall within a narrow range and exhibit minimal tidal dependence. Surface water salinities are more variable and display strong tidal influence with a noticeable drop in salinity at low tide. The anchor station lies within the influence of the fresh water plume from the Saint John River (see Figures 3 and 4) and, as a result, salinities as low as 27°/$_{oo}$ were observed. SPM values measured for bottom water samples had a range of 3.69 to 26.84 mg/l (average, $\bar{x}$ = 18.30 mg/l) and surface water samples ranged from 1.72 to 17.19 mg/l ($\bar{x}$ = 8.50 mg/l).

Current meters were deployed at the anchor station at depths of 5 (surface) and 35 (bottom) metres to monitor current velocity and direction in the vicinity of the reactor outfall. Bottom current velocities ranged from 0.1 to 0.75 m/s. The lows of 0.1 to 0.2 m/s were associated with tidal reversal and low SPM concentrations illustrated in Figure 8. The SPM peaks illustrated in Figure 8 were slightly out of phase with incoming tidal currents of approximately 0.75 m/s surface currents correlate well with changing salinity and tidal conditions as expected. Maximum current velocities were observed with falling tides and reached speeds of 1.0 to 1.2 m/s. In general, current meter results indicate that the resuspension of bottom material, due to changing current conditions and subsequent

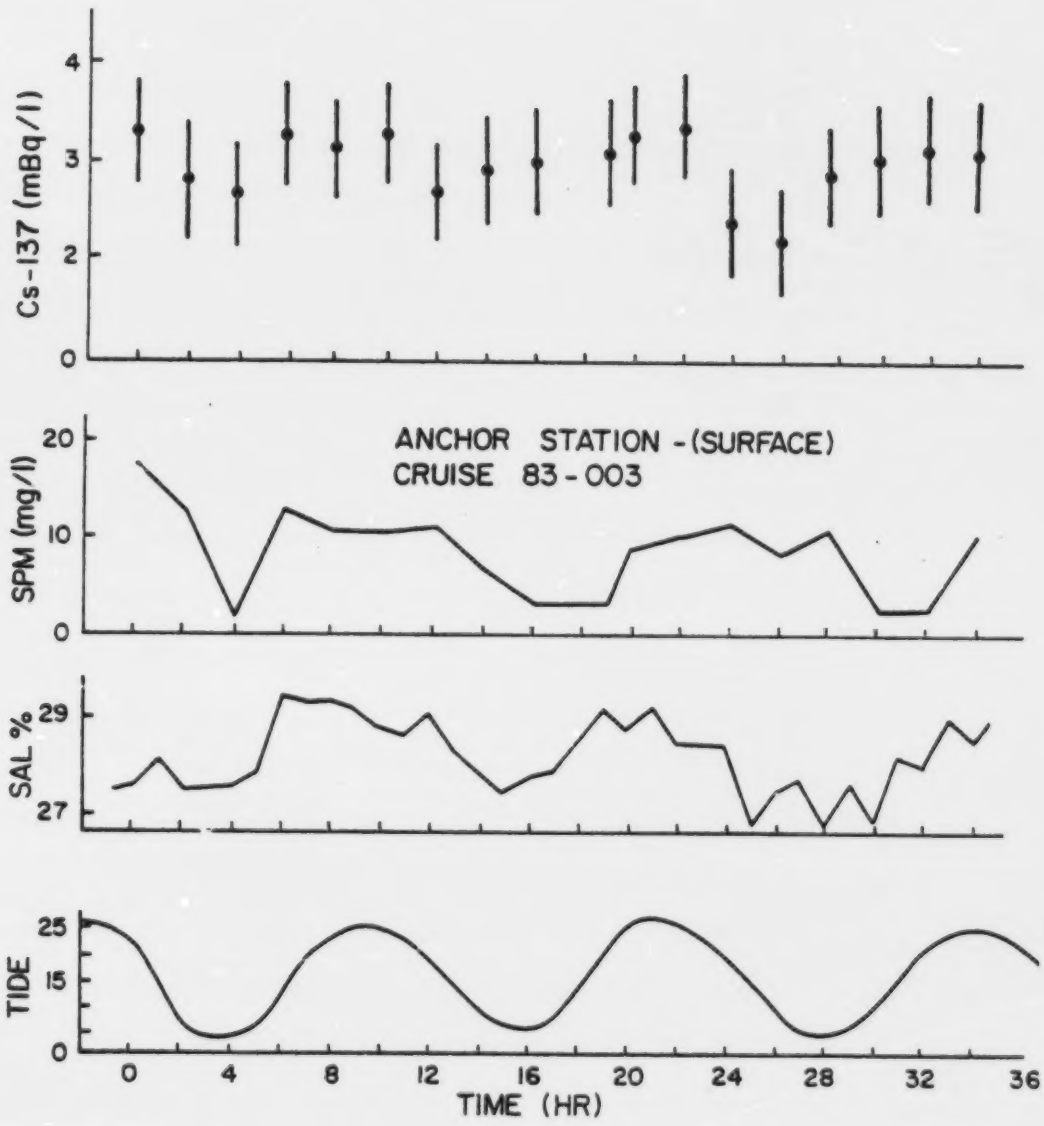

Figure 7. Cs-137,SPM and salinity plotted as a function of time for surface water samples collected at the anchor station during cruise 83-003.

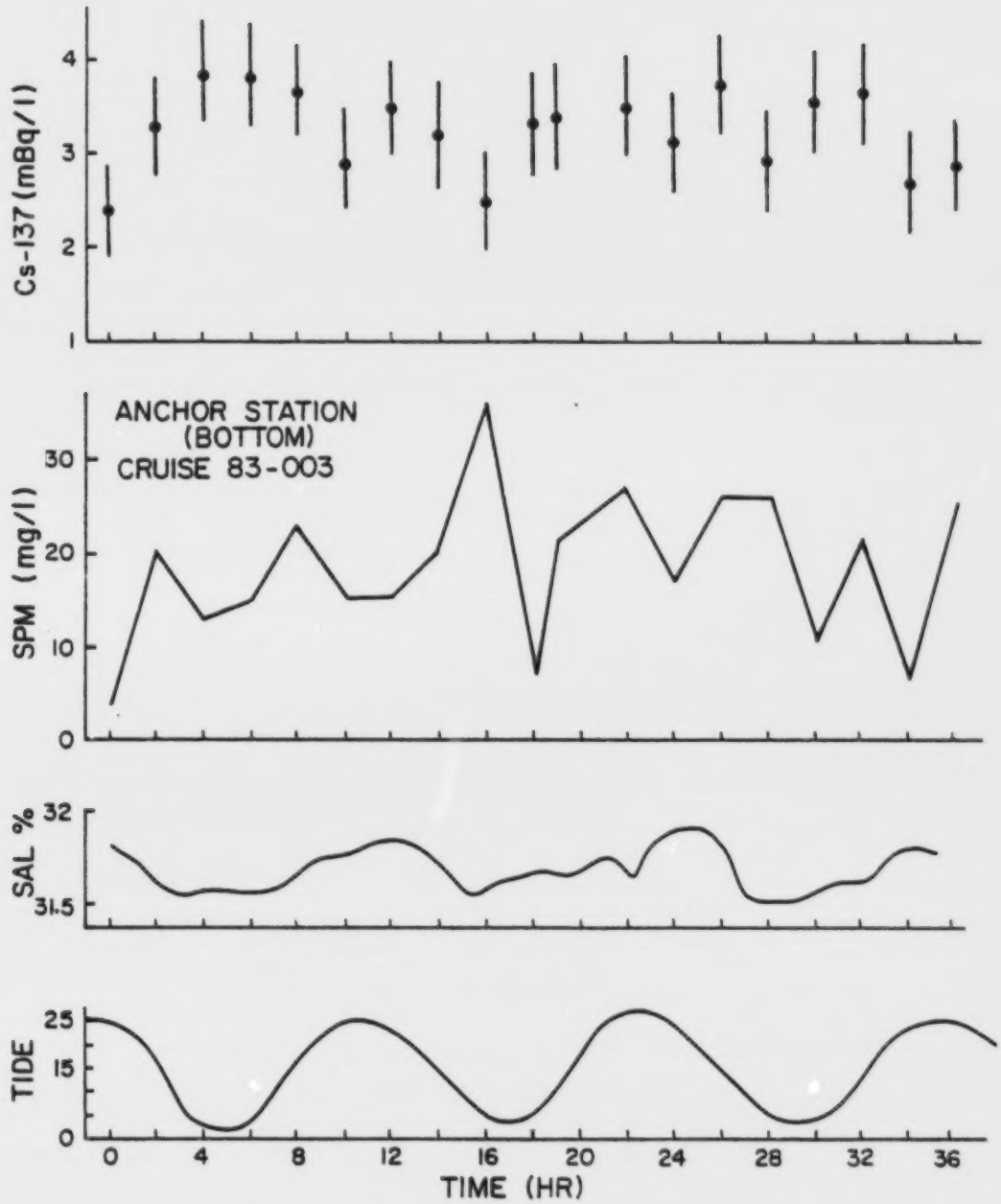

Figure 8. Cs-137, SPM and salinity plotted as a function of time for bottom water samples collected at the anchor station during cruise 83-003.

transport with the rising tide during periods of maximum current velocity, may be a possible mechanism to explain peak SPM concentrations observed in bottom waters at the anchor station.

The Cs-137 results for samples collected at the anchor station are presented in Figures 7 and 8, and in Table 4. Average surface water values of 2.97 ±0.44 mBq/l are slightly lower than bottom water values of 3.27 ±0.44 Bq/l but are within the uncertainies error of bottom water activities. Cs-137 levels found on previous spring cruises (Table 5) were slightly higher (Cruise 81-010; surface $\bar{x}$ = 3.64 ±0.34 m Bq/l, bottom $\bar{x}$ = 3.51 ±0.34 Bq/l) but this may be function of variable spring runoff.

The range of Cs-137 values found at the anchor station 2.23 mBq/l to 3.88 mBq/l is similar to the range found over the entire sampling area of 2.60 to 4.76 mBq/l and supports the contention that tidal mixing will produce rapid dilution of any radioactive plume.

2.3.1.2 Gamma-Emitting Radionuclides

Neutron activation products of transition metals present in reactor support and encasement materials, such as Zn-65, Co-60, and Mn-54, are environmentally important radionuclides resulting from both nuclear weapons fallout and effluents from reactor facilities. They tend to be physiologically essential to marine organisms and concentration factors of 10^3 to 10^5 from seawater have been observed (Robertson, 1974).

The gamma-emitting radionuclides listed in Table 6 are concentrated from seawater by adsorption onto chelex-100 (with the exception of I-131, and Cs-137). The average retention efficiency of 90% was determined using an NBS mixed gamma radionuclide standard. The detection limits in Table 6 are based on an assumed water volume of 50 litres with eluted samples

Table 6. Comparison of detection limits for radionuclides in dissolved and particulate phases.

Nuclide	Half life (Days, years)	Detection limit Suspended matter (mBq/l)	Detection limit Dissolved (mBq/l)	Expected Activities** Suspended matter (mBq/l)	Expected Activities** Dissolved (mBq/l)
Ag-110m	250.4 d	0.84	2	0.0002	0.02
Ce-141	33.0 d	72	5	0.049	0.002
Ce-144	284.4 d	3.3	12	0.56	0.022
Co-58	71.2 d	4.9	-	-	-
Co-60	5.27 y	0.60	3	0.25	0.29
Cr-51	27.7 d	1494	30	16.6	39.0
Cs-134	2.06 y	0.51	3	0.001	0.065
Cs-137	30.0 y	0.47	-	-	-
I -131	8.06 d	-	-	0.02	151.51
Mn-54	321.6 d	0.80	3	0.009	0.015
Nb-95	35.2 d	-	4	4.91	1.15
Ru-103	39.4 d	31	4	-	-
Ru-106	368.0 d	6.6	23	-	-
Zn-65	244.1 d	2.0	5	-	-
Zr-95	65.0 d	11	7	3.42	0.40
H -3		-	1500	0.006	656.59

* Calculation based on seawater volume of 50 ℓ, SPM concentration of 8.5 mg/l, and counting time of 1500 min one month after sample collection.

** Radionuclide concentration expected at the cooling water outfall. Calculated from liquid effluent monthly summary (Table 2) and coastal partition coefficients compiled by OECD, 1984.

counted for 1500 minutes, one month after the sample collection.

Radionuclide concentrations expected at the cooling water outfall have been calculated using NBEPC liquid effluent data (Table 2) and recommended values for coastal water partition coefficients (OECD, 1984).

$$\frac{\text{Total Activity released/year}}{\text{Volume of Water released/year}} = Act_{sol} + Act_{part} = Act_{sol}(1 + K_D \times [SPM])$$

where K_D is the partition coefficient, for a SPM concentration of 8.5×10^{-6} g/ml and for a yearly effluent volume of 5.5×10^{11}. This allows the calculation of expected concentrations for both dissolved and particulate radionuclide species being released from the Point Lepreau NGS. A comparison of AERU detection limits with expected activities for dissolved species indicates that, even before dilution in the receiving waters of the Bay of Fundy, the concentration of radionuclides released are below AERU detection limits. As expected, all gamma-emitting radionuclides were below detection limits. Radioecological studies of activation products released from two boiling water reactors in Sweden found that Co-60 was first detected in seawater after three years of two-unit operation. Seawater concentrations of 1.3 to 5.4 mBq/l were found at sampling sites 5 km from the cooling water outfall (Nilsson et al., 1984). This suggests that all of the radionuclides being released form the Point Lepreau NGS probably will remain below AERU detection limits for several years.

2.3.1.3 Tritium in Seawater

The major tritium inputs into the environment in the past have been associated with fallout from nuclear weapons tests, in addition to the naturally occurring input from cosmogenic interactions in the upper atmosphere. Environmental releases of tritium from the Point Lepreau NGS will

be substantially greater than those for any other radionuclide under normal operating conditions due to the use of heavy water (D_2O) as the moderator and coolant and elevated levels of tritium associated with reactor releases are likely to be detectable in a range of environmental phases.

Water samples collected for tritium analysis in the Bay of Fundy were distilled under vacuum and counted for 1000 minutes in a liquid scintillation counter using methods outlined in previous reports. The results for cruise 83-003 are given in Table 4. The range in tritium values for cruise 83-003 was <1.3 to 3.4 ±1.6 Bq/l and the majority of seawater samples analyzed were below the detection limit. Tritium values for this cruise are comparable with those found during the pre-operational program (Table 5) indicating that no measurable increase in the overall seawater tritium activity occurred in the Bay of Fundy.

In addition, water samples were collected for tritium analysis at the surface during the April cruise 83-003 and at the surface and bottom during a second thermal plume study in September. A detailed discussion of these results is presented in Section 2.4.1.

2.3.2 Nutrients

The oceans, and particularly coastal waters, are non homogeneous mixtures with regard to chemical composition. In the majority of coastal waters, precipitation and freshwater runoff exceed evaporation from the ocean's surface. The less dense freshwater mixes in the surface layers and moves away from the coast, being replaced by a subsurface input of more saline deep water. This process helps to maintain the chemical inhomogeneity of coastal waters by replenishing chemicals lost from the surface layer by particulate settling and biological action, and the replenishment of

depleted surface waters with nutrient-rich bottom water is vital to the high primary productivity characteristic of shelf seas.

Water samples for nutrients and salinity determinations were collected at selected water depths using 12-litre Niskin bottles. Nutrient samples were drawn directly from the Niskin bottles and stored frozen for subsequent analysis by standard auto-analysis techniques. Unfiltered water samples were also collected for salinity determinations. Selected results for nutrient analysis for cruise 83-003 are presented in Table 4 and the values measured are within the ranges of values measured on previous Bay of Fundy cruises. The inverse silicate-salinity relationship present during previous cruises is again evident for cruise 83-003 ($r = -0.68$, $n = 37$) but weaker than that observed during the May cruise in 1979 (79-007; $r = 0.998$, $n = 49$). This difference is probably due to the narrower range in salinity and silicate values measured during cruise 83-003.

2.3.3 Sediment Studies

Radionuclides released from the Point Lepreau NGS will be partitioned between soluble and suspended particulate matter phases to an extent dependent on their respective particle-water distribution coefficients. The more particle-reactive radionuclides such as Co-60 and Zn-65 will follow the transport pathways for particulate matter through the water column and will ultimately be deposited in the sediments. Sites of net sediment deposition within the western Bay of Fundy warrant investigation because they may ultimately record the historical record of particle-reactive radionuclide releases from the Point Lepreau NGS. Further, knowledge of radionuclide sediment inventories is critical to the determination of the availability of these radionuclides for uptake by bottom

dwelling organisms and to assess the importance of post-depositional remobilization of radionuclides by particle resuspension, bioturbation and diffusion. Finally, the sediment inventory of radionuclides may represent a significant fraction of the total budget for radionuclide releases from the Point Lepreau NGS which must be determined in order to estimate net radionuclide fluxes through different environmental phases.

Classification of the sediments on the basis of their relative sand and mud content gives the distribution pattern for the western Bay of Fundy indicated in Figure 9 (Loring, 1979). The finest grain sediments are found in the Quoddy region, west of Point Lepreau and extending in a lobe south of Grand Manan Island, a pattern that is generally consistent with the distribution pattern of LaHave clays (Fader et al., 1977). Particle size is the main factor controlling trace metal concentrations in the Bay of Fundy because the adsorption of metals onto the detrital host mineral particles increases with the particle surface area. Therefore, the finer offshore sediments in the Quoddy regions are a sink and an enrichment area for trace metals introduced from both natural and industrial sources such as the St. Croix drainage basin, coastal industries and offshore dredge disposal sites (Loring, 1982).

Sediment samples were collected at various stations during the 1983 cruise in the Bay of Fundy using box and Lehigh gravity coring devices. The cores were sub-sampled at 1 cm intervals and the samples were returned to the laboratory for analysis. Measurements of Pb-210, Ra-226, Cs-137 and Pu-239, 240 were conducted on sediment samples by methods previously outlined in Smith et al. (1982) and Ellis et al. (1984). The additional Pb-210 measurements conducted on these samples permit a more detailed description of Pb-210 distributions in the sediments of the western Bay of Fundy.

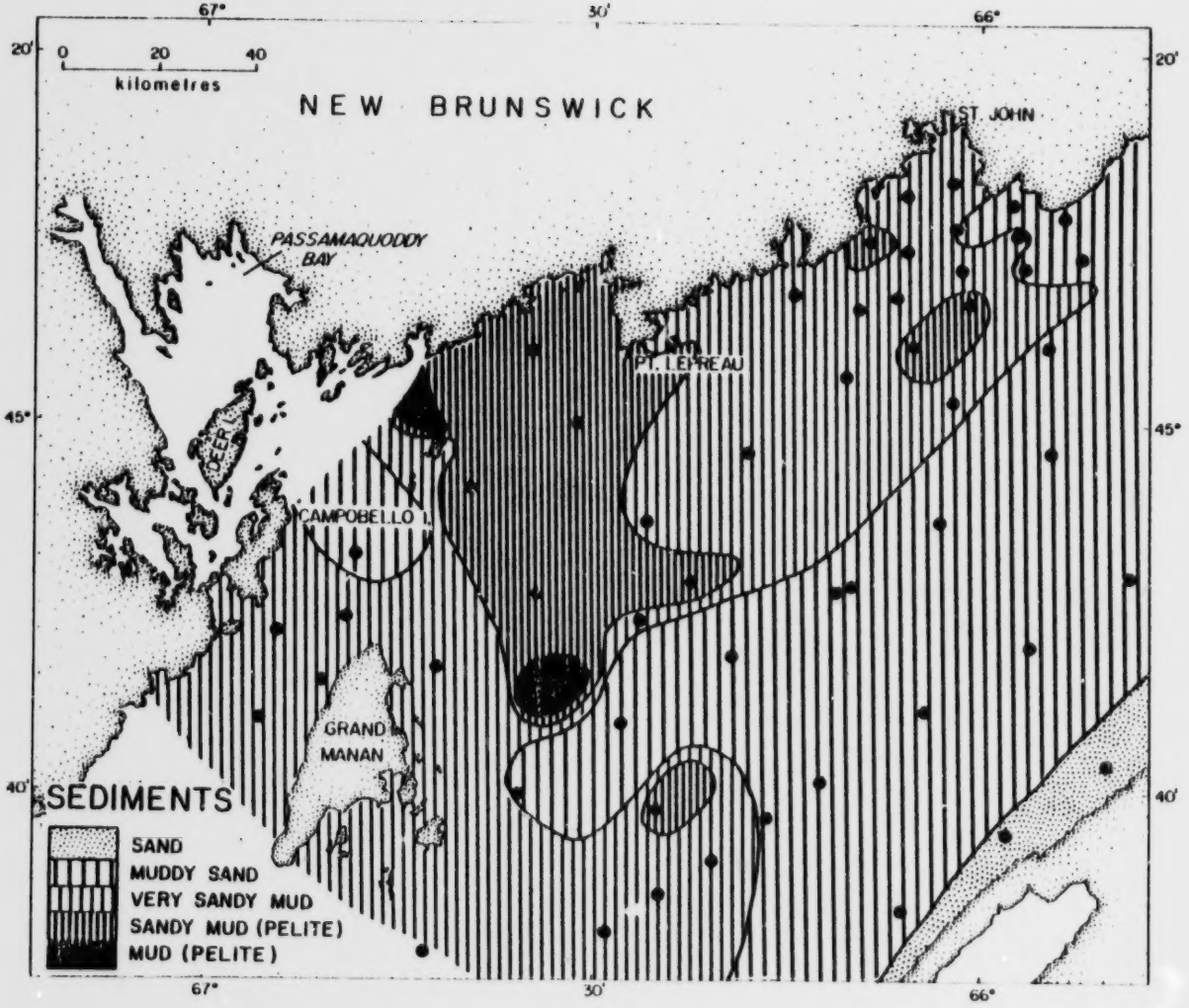

Figure 9. Particle size distribution of sediments in the western Bay of Fundy. Reproduced from Loring (1979).

Pb-210 ($t_{1/2}$ = 22.3 yr) is a naturally-occurring member of the U-238 decay series which is introduced into coastal waters at a relatively constant rate as a result of the radioactive decay of Rn-222 in the atmosphere. Pb-210 is rapidly scavenged by particulate matter in the water column and accumulates as an unsupported excess in the sediments. Measurements of the excess Pb-210 activity, $A_{Pb\text{-}210_{ex}}$ (equal to the total Pb-210 activity minus the supported Pb-210 activity due to radioactive decay of Ra-226 within the sediments), as a function of sediment depth can be used to determine sedimentation rates, rates of sediment mixing by bioturbation, or to identify anomalous depositional events associated with sediment slumping (Smith and Walton, 1980).

The excess Pb-210 inventory, $I_{Pb\text{-}210_{ex}}$ (integrated quantity of excess Pb-210 in a core) is proportional to the total flux of excess Pb-210 to the sediments, which, in turn, is a function of the sedimentation rate of fine-grained particulate material. The excess Pb-210 inventories in the western Bay of Fundy can be regionally characterized by low (<30 dpm cm^{-2}), medium (30-100 dpm cm^{-2}) and high (>100 dpm cm^{-2}) excess Pb-210 inventories as illustrated in Figure 10. The highest Pb-210 inventories are found in the Quoddy region, near the northern approaches to Passamaquoddy Bay, where the sediments consist of fine-grained muds (Figure 9). The fine-grained sediments in this region constitute a net depositional sink, both for Pb-210 and other particle reactive radionuclides, in addition to particle-reactive trace metals such as Zn and Hg, (Loring 1982). In contrast, the sediments in the immediate vicinity of Point Lepreau, which grade into sandy muds, are characterized by lower inventories of Pb-210. This latter relationship is consistent with the inhibition of deposition of fine-grained material as the result of the strong residual bottom currents in

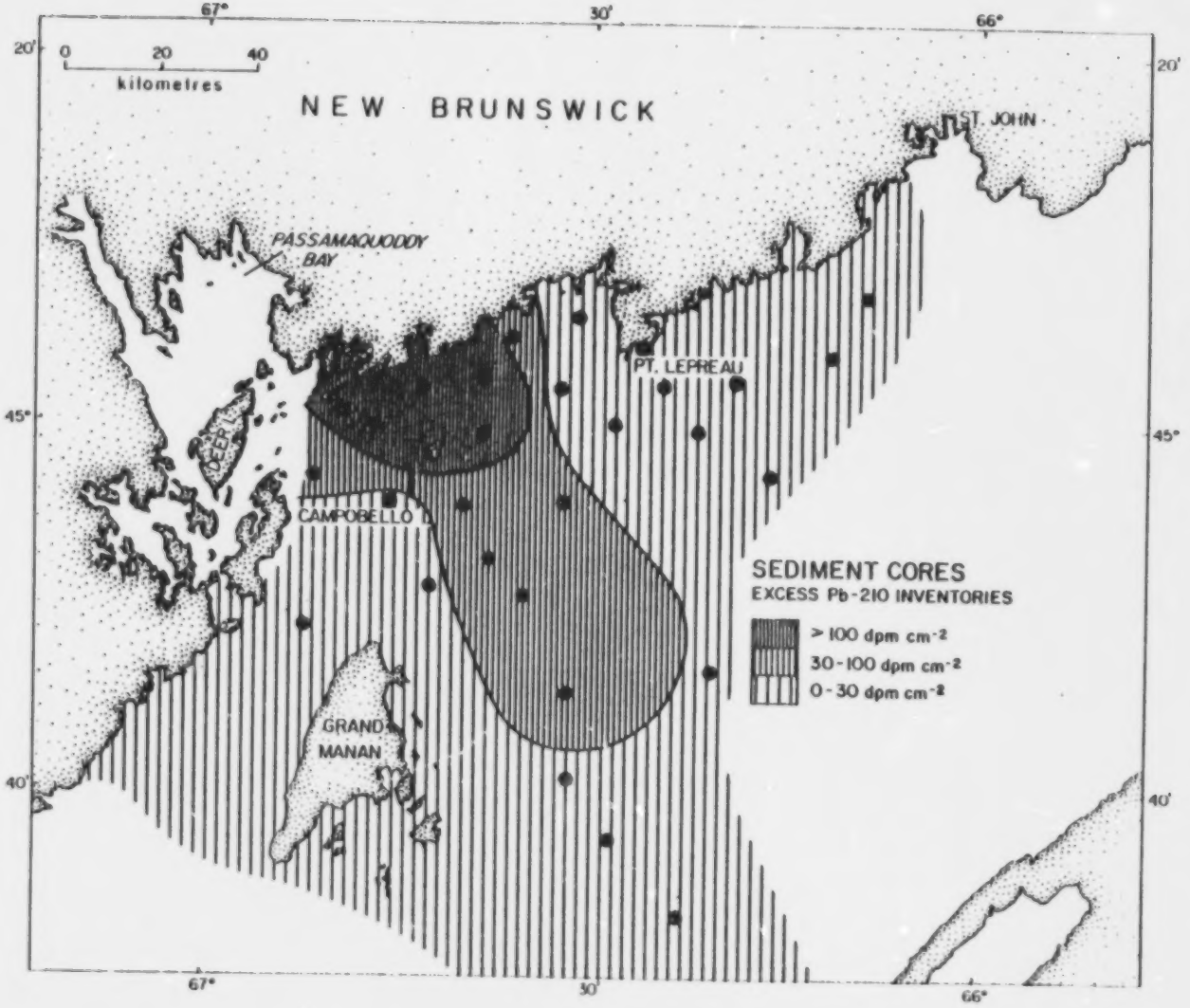

Figure 10. Excess Pb-210 inventories in sediment cores (filled circles) collected in the western Bay of Fundy.

this region. Although particle-reactive radionuclides released from the Point Lepreau NGS may temporarily reside in sediment regimes near Point Lepreau, the final repository for these substances is the fine-grain sediment regime of the Quoddy region.

The levels and distributions of Pu-239, 240 and Pu-238, determined using methods outlined in Ellis et al. (1984), were measured at station 5 where the excess Pb-210 inventory was estimated to be 60 dpm cm^{-2} and at station 41 where the inventory of Pb-210 was measured to be 139 dpm cm^{-2}. At station 41, an area of high sedimentation of fine-grained particles, the Pu-239 inventory was estimated at 2.08 dpm cm^{-2}, in good agreement with previous measurements in this area. The Pu-239 inventory estimated for station 5, characterized as a intermediate depositional area, at 0.43 dpm cm^{-2} is a typical value for this regime. Therefore no increase in the plutonium inventory in the sediment was observed at either location as a result of the operation of the Point Lepreau NGS.

2.4 Thermal Plume Study

The generation of electricity by all thermal processes is accompanied by the production of waste heat that must constantly be removed by means of a cooling water stream and ultimately dispersed into the surrounding environment. The Point Lepreau NGS has chosen the 'once through' cooling system with offshore intake and discharge designed to utilize the large supply of seawater readily available and to take advantage of the rapid mixing present in the Bay of Fundy to disperse waste heat.

The effects of cooling water discharge are generally reflected in the form of changes in the composition of biological communities and in the characteristics of the ecosystem within the water areas affected by the

temperature increase. The impacts of artificial temperature increase can be summarized as follows:

(1) Temperature increases affect the physical properties of water, i.e., density, viscosity, vapour pressure, and solubility of dissolved gases. Consequently, processes such as particle settling, stratification, circulation, and evaporation can be influenced by temperature changes.

(2) Increased temperatures affect the rate of chemical reactions and can speed up the formation of compounds or change dynamic chemical equilibria. A rise in temperature of 10°C approximately doubles metabolic rate for marine organisms (Clarke et al., 1973).

(3) Environmental temperatures are important to physiological processes such as reproduction, development, and metabolism. Work carried out by Wright et al. (1983) on the temperature tolerance of embryo and larval bivalves pointed out that elevated temperatures increase mortality, but that different species and stages of development are less tolerant than others. Temperature anomalies can also block the passage of anadromous fish, greatly reducing future populations.

(4) Temperature increases can result in synergistic action, i.e., the simultaneous effects of separate agents is greater than the total sum of individual effects. Prime examples associated with temperature increases are increased toxicity of some materials and increases in the susceptibility of fish to diseases.

(5) Increased temperatures may reduce species diversity in a community and stimulate populations of individual species to nuisance conditions. In estuaries, algae proliferating in the warm water can

clog the filtering apparatus of shellfish and cause their death (Clarke et al., 1973).

It is often easier to detect the influence of heat on the stationary elements of an ecosystem rather than the mobile ones. There are several documented cases of adverse thermal effects on the benthic community. The discharge from two fossil fuel units at Turkey Point (Biscayne Bay, Florida) was shown to be responsible for the demise of 91% of the bottom grasses at a distance of 410 metres away. Heat from these units also caused an excessive growth of blue-green alge, which displaced better forms of food in the estuary. A report on the Northport plant (Long Island Sound, N.Y.) described the plume area as an impoverished habitat with low benthic biomass within 1.5 km of the plant outfall (Clark et al., 1973).

Less common are reported incidences of fish mortality including fish kills related to 'cold shock.' Fish that become acclimatized to high temperatures in the thermal plume can undergo thermal shock when plant shutdowns cause a rapid drop in water temperature. The fish species, menhaden or 'mossbunkers,' which had taken up residence in the thermal plume from the Oyster Creek Nuclear Power Plant suffered massive fatalities after a plant shutdown. When thousands of fish were killed at Turkey Point in Florida, the cause was given as high temperature shock from plant discharge temperatures ranging from 35°C to 38°C (Clark et al., 1973).

The original Environmental Impact Statement (EIS) for the Point Lepreau NGS prepared by MacLaren Atlantic Ltd. (1977) contained predictions of temperature changes as a result of the operation of the Point Lepreau NGS. The maximum temperature of the cooling water at discharge to the Bay of Fundy was expected to reach 24°C, which would occur in late summer and fall when the intake temperature is at a maximum. The average increase in

cooling water temperature in the condensor was predicted to be 13.3°C. Temperature changes at the outfall itself were expected to be of the order of 3 to 5°C for two-unit operation.

The use of vast quantities of water for cooling purposes can result in many physical, chemical and biological changes in the receiving waters involved. Whether the physical and chemical changes in water bodies always result in significant biological changes in ecosystems has been the subject of considerable research. Two studies undertaken in the Bay of Fundy, one at the Coleson Cove Thermal Generating Station and the other at the Point Lepreau NGS are discussed below.

A benthic survey was carried out both before and after the construction of the Coleson Cove Thermal Generating Station, located 20 km northwest of Point Lepreau, to determine any effects of thermal discharge from this station (Marine Research Assoc., 1980a). The same transects were occupied and surveyed for marine benthos in both 1974, prior to the operation of the station, and 1980, after the station began operating, by Marine Research Associates. The results of this work indicated that no changes had occurred between 1974 and 1980 in the abundance and distribution of intertidal organisims which could not be explained by seasonality or variations in sampling technique. Since most intertidal organisims can withstand wide temperature fluctuations, no major changes had been anticipated due to thermal emissions from the Coleson Cove Generating Station. The work done at Coleson Cove indicated that ecological changes were taking place but it was difficult to determine whether these changes were the result of local thermal effects or part of a general progressive degradation of the Lorneville coast resulting from pollution and dredging.

An ecological baseline study of benthic communities was begun at

Point Lepreau in order to document changes occurring at the outfall. During the pre-operational phase, a study of the benthic communities along six transects indicated in Figure 11 was carried out in the winter of 1979-80 to assess baseline population densities of different species of benthic organisms in the vicinity of the Point Lepreau NGS. Four transects (1, 3, 4, and 5) lie within the zone of influence of cooling water outfall, while the two transects (2 and 6) outside this zone are used as controls (Marine Research Assoc., 1980b). The four transects (1, 2, 5, and 6) were subsequently sampled a second time during the summer of 1980 in order to characterize the seasonal variability in benthic population distributions (Marine Research Assoc., 1980c). Each transect lay within similar bottom types in running from the intertidal zone to a depth of approximately 15 metres below the maximum water line and benthic biota were identified along each transect. In addition, organisms were collected from a 0.25 m^2 quadrate grid and returned to the laboratory for identification and dry-weight determinations. A third benthic survey will be carried out during the operational phase to document any changes in the benthic population.

Ultimately the impact of thermal pollution on the environment will depend on the extent and duration of the thermal plume. The ensuing dispersal of heat through the receiving waters and into the atmosphere is controlled by current velocity, turbulence, temperature difference between air and water, the humidity of the air and the speed and direction of the wind.

2.4.1 Thermal Plume Field Work

The physical oceanography component for the thermal plume study was organized and supervised by Gary Bugden, (PLEMP working group; Appendix 1) who was also responsible for the analysis of the results.

Figure 11. Six transects used in baseline benthic study at Point Lepreau ,N.B. Transects 1, 3, 4 and 5 lie within zone of cooling water outfall, while transects 2 and 6 were used as control sites.

In mid-April and late September of 1983, two temperature-salinity surveys were performed near the cooling water outfall of the Point Lepreau NGS. Vertical profiles of temperature and salinity were obtained using a Guideline portable CTD system, and water samples were collected for tritium analysis. Twenty nine stations were occupied during each survey. A brief description of some of the observations obtained is given below.

The April survey was conducted on April 15 and 16 as part of the C.S.S. Dawson cruise 83-003. The Dawson's launch was used to occupy the station pattern indicated in Figure 12. The results of this survey are outlined in Table 7. The vertical structure of the water column near the outfall during this survey was characterized by the presence of a low salinity surface layer (Figure 13) due to the spring freshet from the Saint John River and other smaller rivers near Point Lepreau. The highly stratified conditions encountered are not unusual as the same phenomenon was observed during cruise 79-007 in May of 1979 before plant start-up (Smith et al., 1981). As a result of this density structure, no coherent surface effects of the heated discharge could be detected. During this survey, only surface H-3 samples were collected and no significant deviations from background levels were observed.

Figure 14 illustrates the surface temperature distribution for some of the occupied stations. The surface temperature distribution in the region of the outfall is similar to that of the neighbouring waters. The thermal plume was present, however, as a mid-depth temperature maximum (Figure 15). The maximum temperature was observed at a depth of approximately 8 m at all stations where it was present. As salinity has a much more profound effect on the density of seawater than temperature, the effect of the low salinity surface layer was to hold the plume at mid-

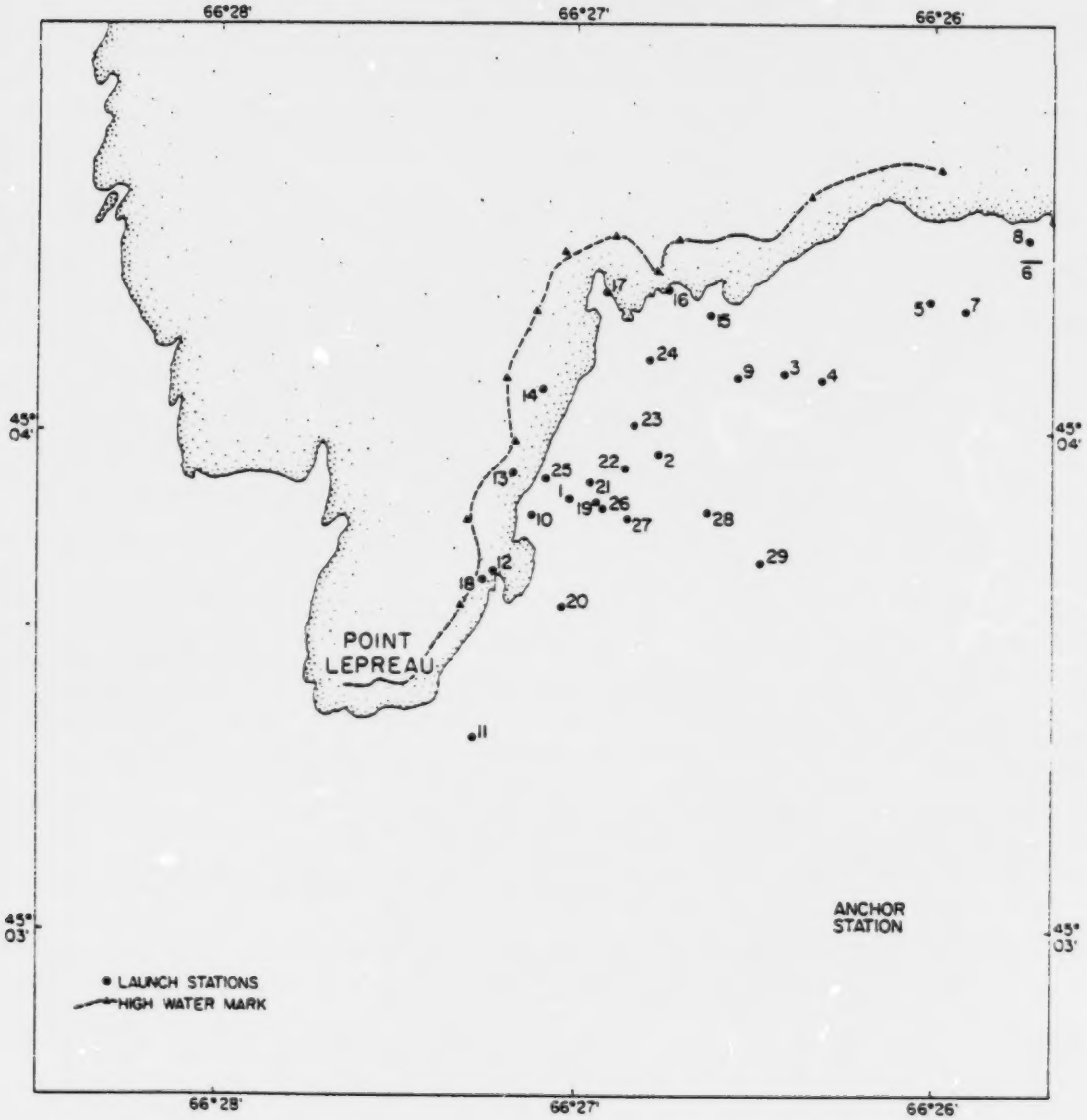

Figure 12. Stations occupied using portable CTD April 15-16, 1983 during cruise 83-003.

Table 7. Results of thermal plume survey conducted on April 15-16, 1983.

Station No.	Date yr/m/d	Time GMT	Depth m	Chem ID	Latitude	Longitude	Surface Temp. °C	Surface Salinity °/₀₀	Surface Tritium (Bq/L)
1	83/04/15	1420	15 m	83-06519	45°03.87'N	66°27.02'W	-	-	<1.4
2	"	1427	8 m	06520	45°03.96'N	66°26.84'W	-	-	-
3	"	1440	11 m	06521	45°04.12'N	66°26.44'W	3.24	-	-
4	"	1450	11 m	06522	45°04.11'N	66°26.33'W	3.23	-	-
5	"	1501	11 m	06523	45°04.27'N	66°26.02'W	3.25	28.47	-
6	"	1508	5 m	06524	45°04.45'N	66°25.46'W	3.31	29.57	-
7	"	1516	11 m	06525	45°04.25'N	66°25.92'W	3.28	28.63	-
8	"	1645	27 m	06526	45°04.40'N	66°25.74'W	3.41	29.02	-
9	"	1657	11 m	06527	45°04.11'N	66°26.57'W	3.45	29.42	-
10	"	1706	17 m	06528	45°03.84'N	66°27.14'W	3.47	29.68	-
11	"	1715	15 m	06529	45°03.40'N	66°27.30'W	3.52	29.25	-
12	"	1724	11 m	06530	45°03.73'N	66°27.25'W	3.59	29.76	-
13	"	1732	6 m	06531	45°03.92'N	66°27.19'W	3.47	29.47	-
14	"	1739	4 m	06532	45°04.09'N	66°27.11'W	3.61	29.33	-
15	"	1749	17 m	06533	45°04.24'N	66°26.64'W	3.57	29.68	<1.4
16	"	1758	3 m	06534	45°04.29'N	66°26.76'W	3.85	27.74	<1.4
17	"	1802	4 m	06535	45°04.29'N	66°26.93'W	3.67	28.27	<1.4
18	"	1812	10 m	06536	45°03.80'N	66°27.27'W	3.60	29.20	<1.4
19	83/04/16	1247	15 m	06538	45°03.86'N	66°26.96'W	3.13	27.70	<1.4
20	"	1259	18 m	06539	45°03.65'N	66°27.05'W	3.15	27.25	-
21	"	1304	15 m	06540	45°03.90'N	66°26.97'W	3.79	27.89	<1.4
22	"	1309	24 m	06541	45°03.93'N	66°26.87'W	3.29	27.38	-
23	"	1314	13 m	06542	45°04.01'N	66°26.85'W	3.43	27.58	-
24	"	1318	11 m	06543	45°04.14'N	66°26.80'W	3.25	27.59	-
25	"	1325	13 m	06544	45°03.91'N	66°27.09'W	3.25	27.55	-
26	"	1329	18 m	06545	45°03.85'N	66°26.93'W	3.21	27.40	-

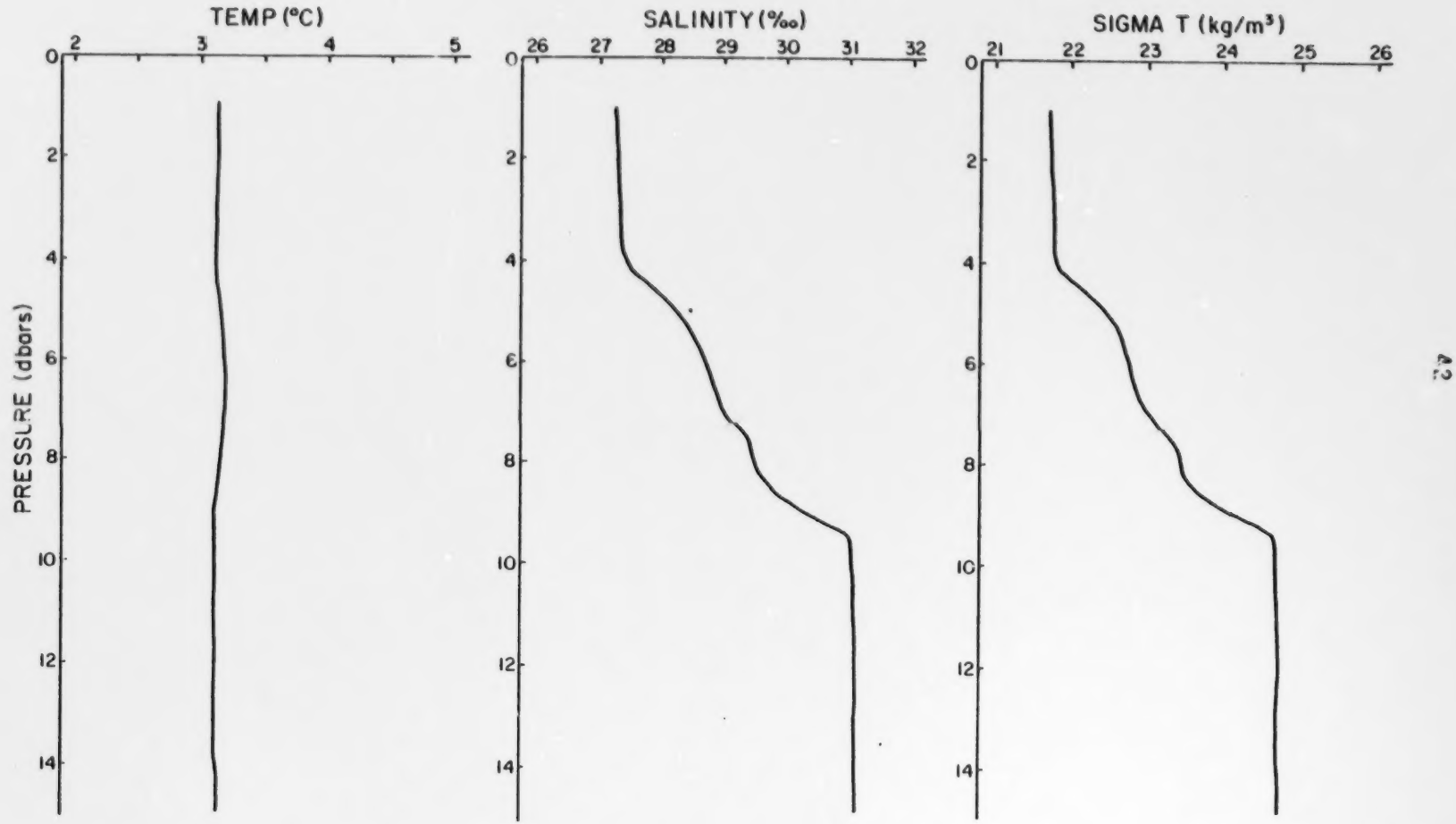

Figure 13. Typical temperature ,salinity and density profiles in the area of the outfall but uneffected by it during the April survey.

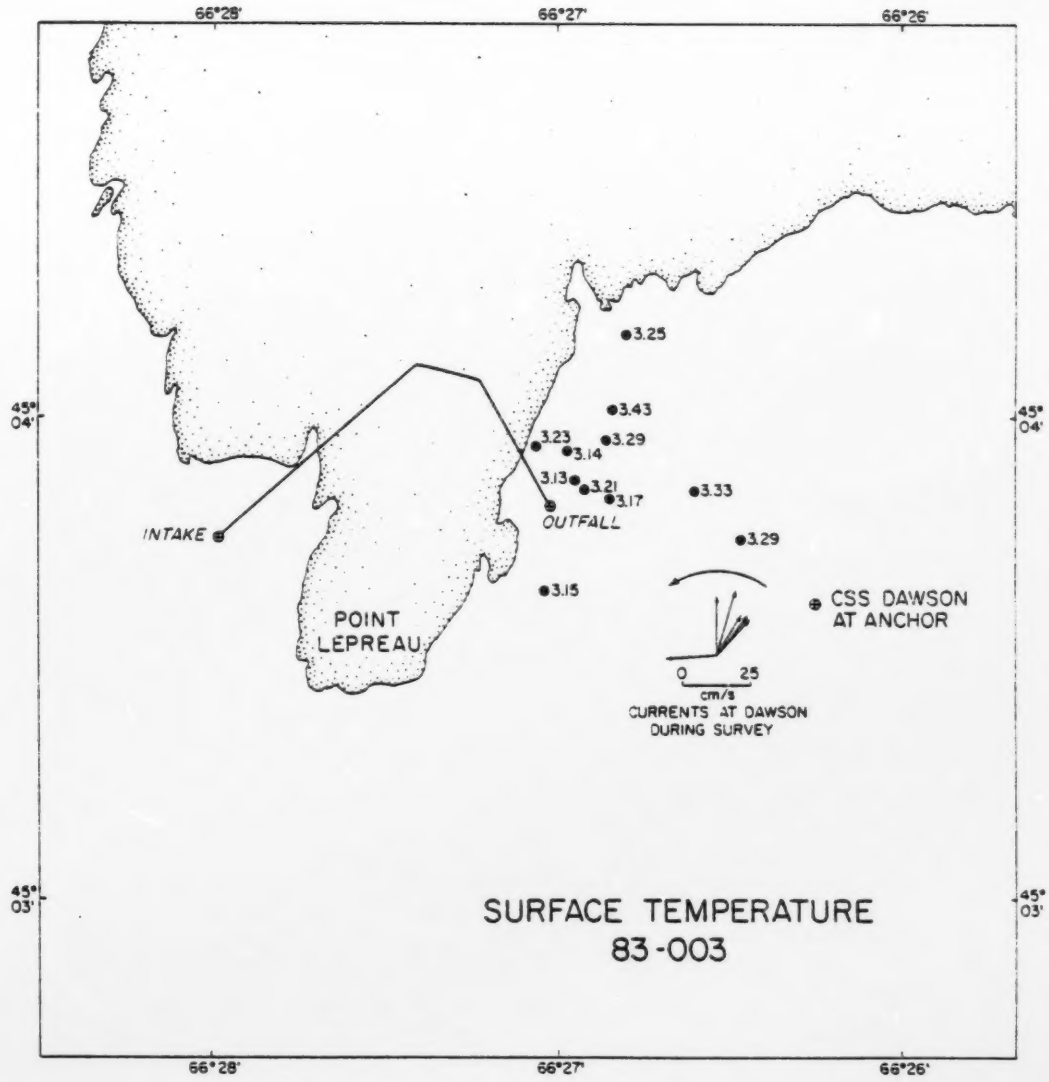

Figure 14. Surface temperature at selected stations during the April survey.

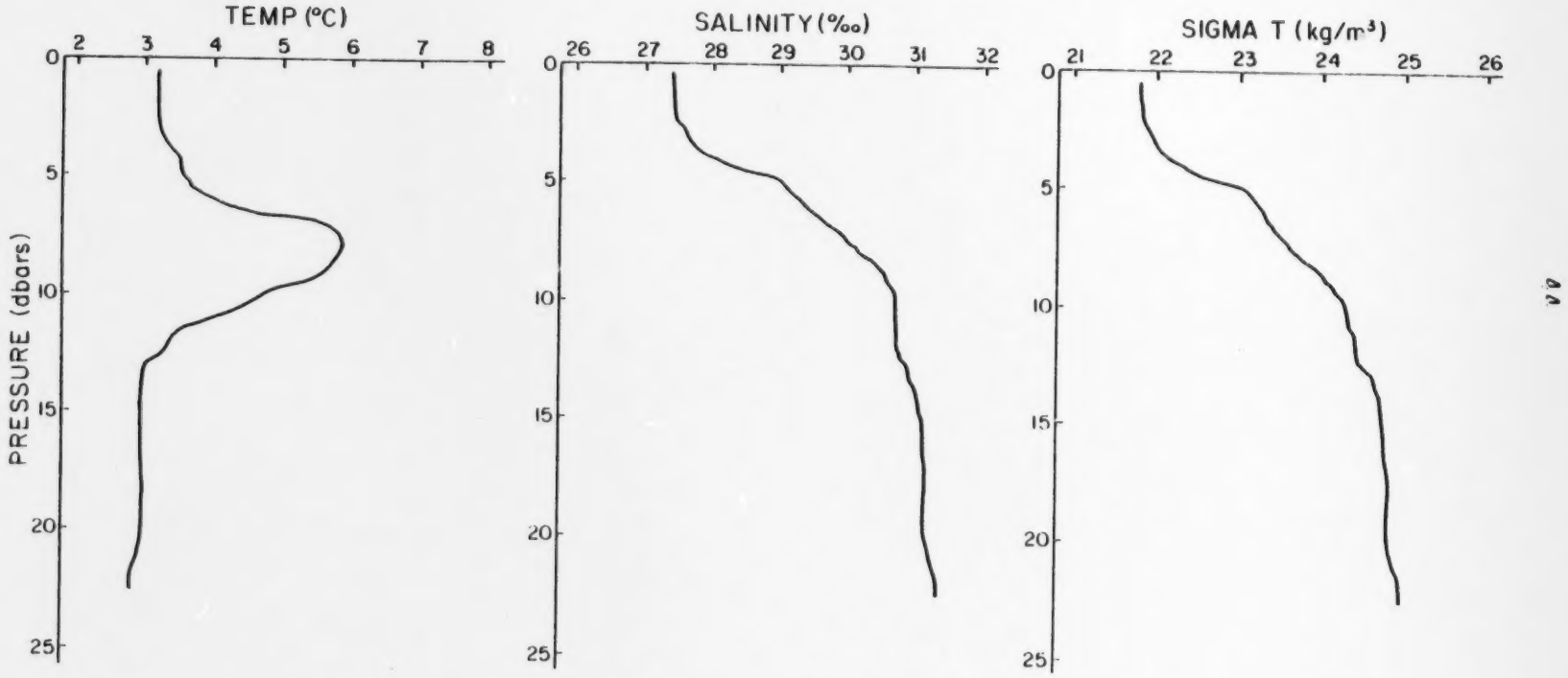

Figure 15. Temperature ,salinity and density profiles showing the thermal effluent trapped at mid-depth.

depth. The effect of the addition of heated discharge water is not sufficient to reduce the density of the mid-depth water to less than that of the surface waters. This resulted in reduced mixing of the effluent with the surrounding waters. Figure 16 shows temperature contours at a depth of 8 m. The maximum temperature increase at the outfall was approximately 3°C and as illustrated skewed in the direction of maximum current velocity. The total area affected by the thermal plume is approximately 1 km^2.

The maximum temperature increase of approximately 3°C is comparable to the maximum temperature predicted for a single-unit operation at low tide at the surface (3°C) but is greater than the maximum temperature predicted for high tide (2°C). Figure 16 may be compared to Figure 17, which illustrates the predicted surface temperature modification for a two-unit operation at low tide (MacLaren Atlantic Limited, 1977). The distribution measured in April is more comparable to the two-unit prediction, although the range of thermal influence of the latter is larger. The original EIS failed to predict the trapping of the thermal plume at mid-depth during spring conditions as a result of increased stratification caused by spring runoff which led to reduced mixing of the thermal plume and a higher increase in temperature than expected for a single unit near the release point.

A follow-up survey was conducted on September 27, 1983, using a chartered fishing vessel. Stations occupied are indicated in Figure 18 and the results are given in Table 8. As shown in Figure 19, water in the vicinity of the outfall is warmer and relatively unstratified compared to the April conditions, as was observed during cruise 79-027, before plant start-up. Near the outfall, the effects of the discharge were visible on the surface as turbulent whorls and boils with the heated effluent being

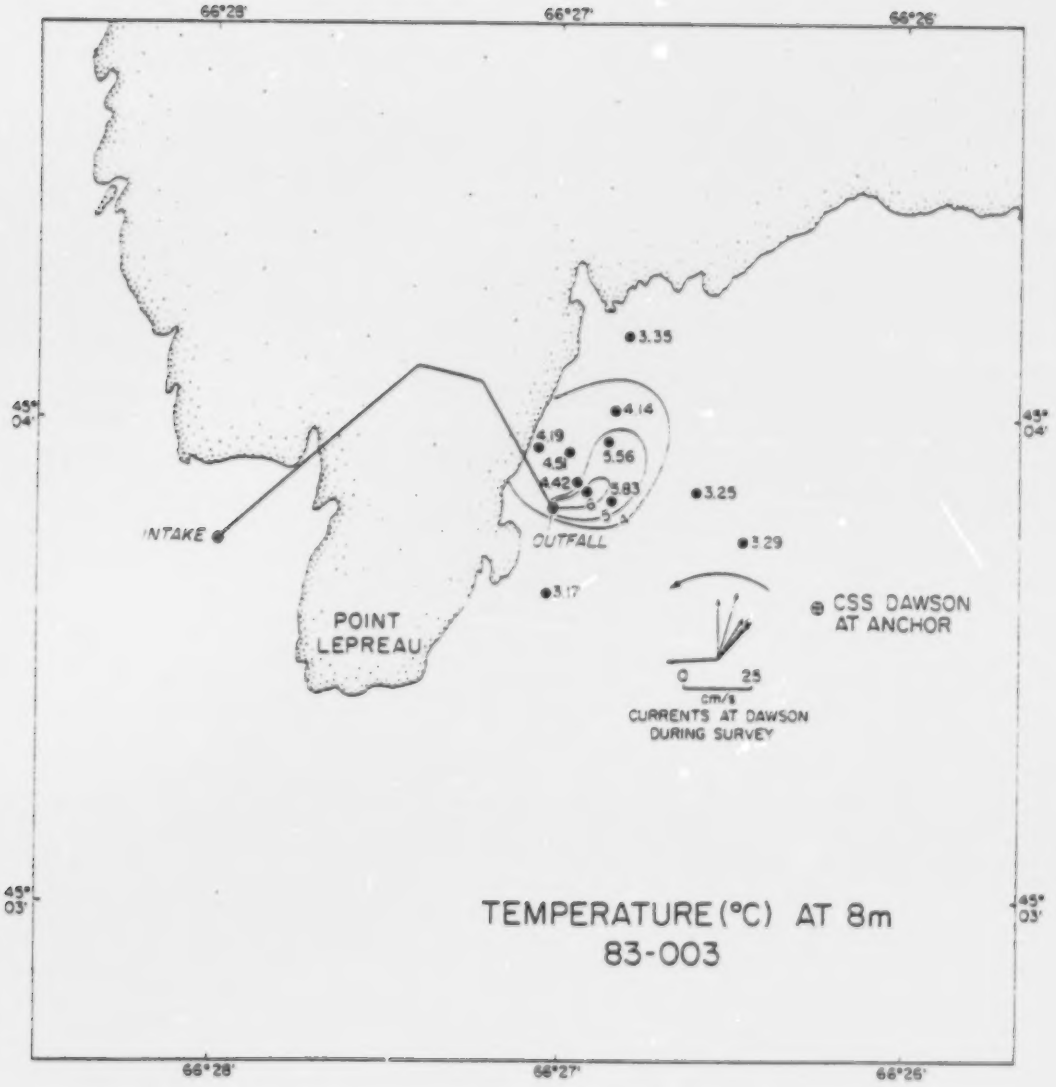

Figure 16. Temperature at a depth of eight meters at selected stations during the April survey.

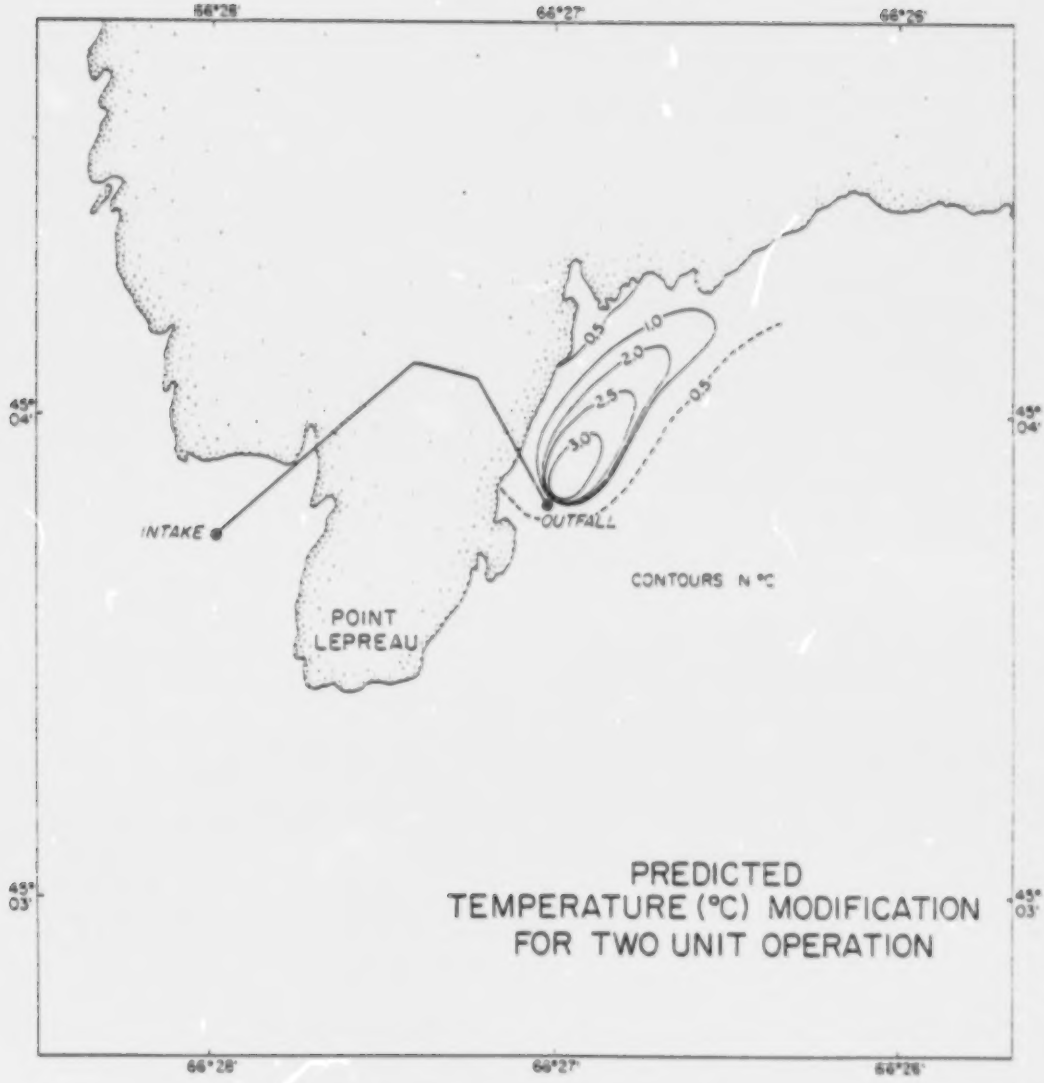

Figure 17. Predicted temperature rise for two unit operation. (MacLaren Atlantic Ltd. 1977)

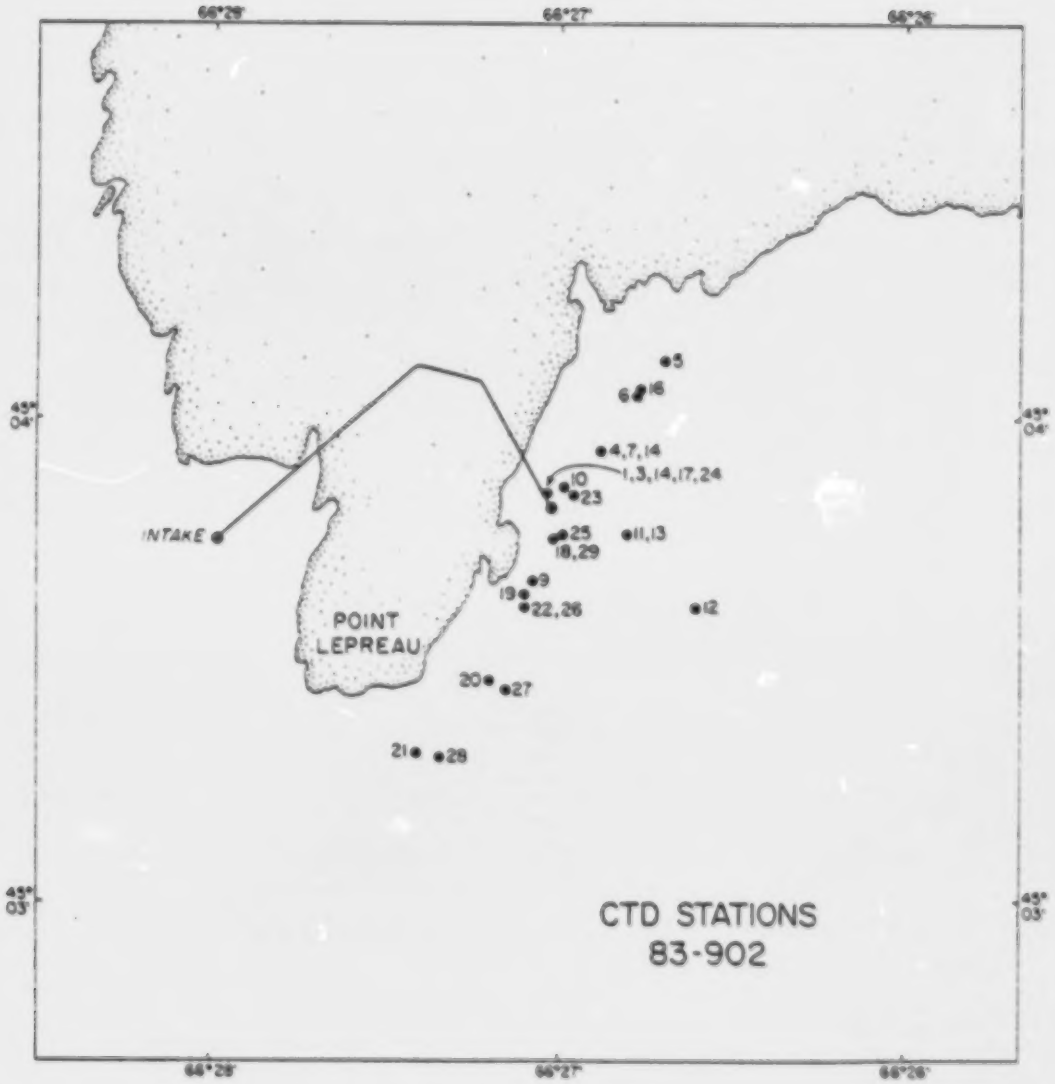

Figure 18. Stations occupied using portable CTD September 27, 1983 during cruise 83-902.

Table 8. Results of thermal plume survey conducted on September 27, 1983.

Station No.	Date yr/m/d	Time GMT	Stn Depth m	Chem ID	Latitude	Longitude	Sampling Depth m	Temp. °C	Salinity °/..	Tritium (Bq/L)
1	83/09/27	1225	14	83-1660	45°03.84'N	66°27.03'W	1	13.6	32.2	<1.5
				1661			8	12.4	32.2	<1.5
3	"	1242	14	1662	45°03.84'N	66°27.03'W	7.9	13.14	32.19	<1.5
4	"	1255	15	1664	45°03.93'N	66°26.88'W	1	12.56	32.2	<1.5
				1665			13.9	11.93	32.17	<1.5
5	"	1309	18	1666	45°04.13'N	66°26.70'W	1	12.18	32.18	<1.5
				1667			9.9	11.90	32.19	<1.5
6	"	1321	20	1668	45°04.05'N	66°26.78'W	1	12.58	31.97	<1.5
				669			10.2	11.93	32.13	<1.5
7	"	1334	22	1670	45°03.93'N	66°26.88'W	1	12.65	32.15	8.7 ± 2.0
				1671			10	12.34	32.16	7.5 ± 2.0
8	"	1343	17	1672	45°03.84'N	66°27.03'W	1	13.89	32.18	4.1 ± 2.0
				1673			10.9	12.05	32.15	3.8 ± 1.9
9	"	1356	20	1674	45°03.67'N	66°27.06'W	1	12.26	32.08	<1.7
				1675			18.7	11.91	32.18	<1.7
10	"	1405	20	1676	45°03.86'N	66°26.99'W	1	13.27	32.18	3.4 ± 1.8
				1677			15.8	11.94	32.16	<1.5
11	"	1413	31	1678	45°03.76'N	66°26.81'W	1	12.19	32.12	<1.5
				1679			30.5	11.89	32.18	3.2 ± 1.8
12	"	1422	40	1680	45°03.61'N	66°26.62'W	1	12.00	32.08	<1.5
				1681			41.0	11.86	32.18	1.6 ± 1.8
13	83/09/27	1433	20	83-1682	45°03.76"N	66°26.81'W	1	12.09	31.96	2.2 ±
				1683			30.5	11.88	32.14	2.7 ± 1.8
14	"	1440	20	1684	45°03.84'N	66°27.03"W	1	13.58	32.00	33.5 ± 1.8
				1685			8.3	12.25	32.11	34.7 ± 2.7
15	"	1447	20	1686	45°03.93'N	66°26.88'W	1	12.55	32.03	54.3 ± 2.1
				1687			10.0	12.00	32.08	7.2 ± 2.2
16	"	1454	22	1688	45°04.06'N	66°26.77'W	1	12.46	32.13	1.8 ± 1.8
				1689			9.6	11.99	32.15	2.7 ± 1.8
										1.8

Table 8. Results ... continued

Station No.	Date yr/m/d	Time GMT	Stn Depth m	Chem ID	Latitude	Longitude	Sampling Depth m	Temp. °C	Salinity °/₀₀	Tritium (Bq/L)
17	"	1503	22	1690	45°03.84'N	66°27.03'W	1	13.60	32.18	5.2 ± 1.8
				1691			10.1	11.96	32.17	9.5 ± 1.9
18	"	1510	18	1692	45°03.76'N	66°27.02'W	1	12.75	32.17	6.9 ± 1.8
				1693			8.6	12.04	32.15	3.1 ± 1.8
19	"	1519	20	1694	45°03.63'N	66°27.10'W	1	12.40	32.14	6.4 ± 1.8
				1695			10.3	11.98	32.15	3.7 ± 1.8
20	"	1527	27	1696	45°03.46'N	66°27.20'W	1	12.80	32.15	13.9 ± 2.0
				1697			10.1	12.00	32.16	<1.9
21	"	1538	27	1698	45°03.30'N	66°27.41'W	1	12.12	32.17	<1.9
				1699			28.6	11.94	32.18	<1.9
22	"	1550	26	9301	45°03.62'N	66°27.09'W	1	12.84	32.05	5.9 ± 2.3
				9302			9.6	11.99	32.16	3.7 ± 2.3
23	"	1602	24	9303	45°03.84'N	66°26.96'W	1	12.84	32.10	30.9 ± 2.6
				9304			10.9	12.01	32.15	<1.9
24	83/09/27	1612	16	83-9305	45°03.84'N	66°27.03'W	1	12.97	32.00	6.2 ± 2.3
				9306			7.8	12.02	32.06	3.7 ± 2.3
25	"	1624	24	9307	45°03.76'N	66°26.99'W	1	12.94	32.10	7.7 ± 1.9
				9308			9.1	12.08	32.12	6.6 ± 1.8
26	"	1633	24	9309	45°03.62'N	66°27.01'W	1	12.37	32.20	16.6 ± 1.9
				9310			9.0	12.23	32.18	7.2 ± 1.9
27	"	1642	31	9311	45°03.44'N	66°27.15'W	1	12.36	32.12	5.5 ± 1.8
				9312			8.1	12.14	32.17	4.0 ± 1.8
28		1651	33	9313	45°03.30'N	66°27.36'W	1	12.05	32.07	<1.5
				9314			8.1	12.03	32.12	<1.5
29	"	1708	24	9315	45°03.75'N	66°28.02'W	1	12.40	32.06	3.0 ± 1.8
				9316			22.4	11.81	32.23	<1.5

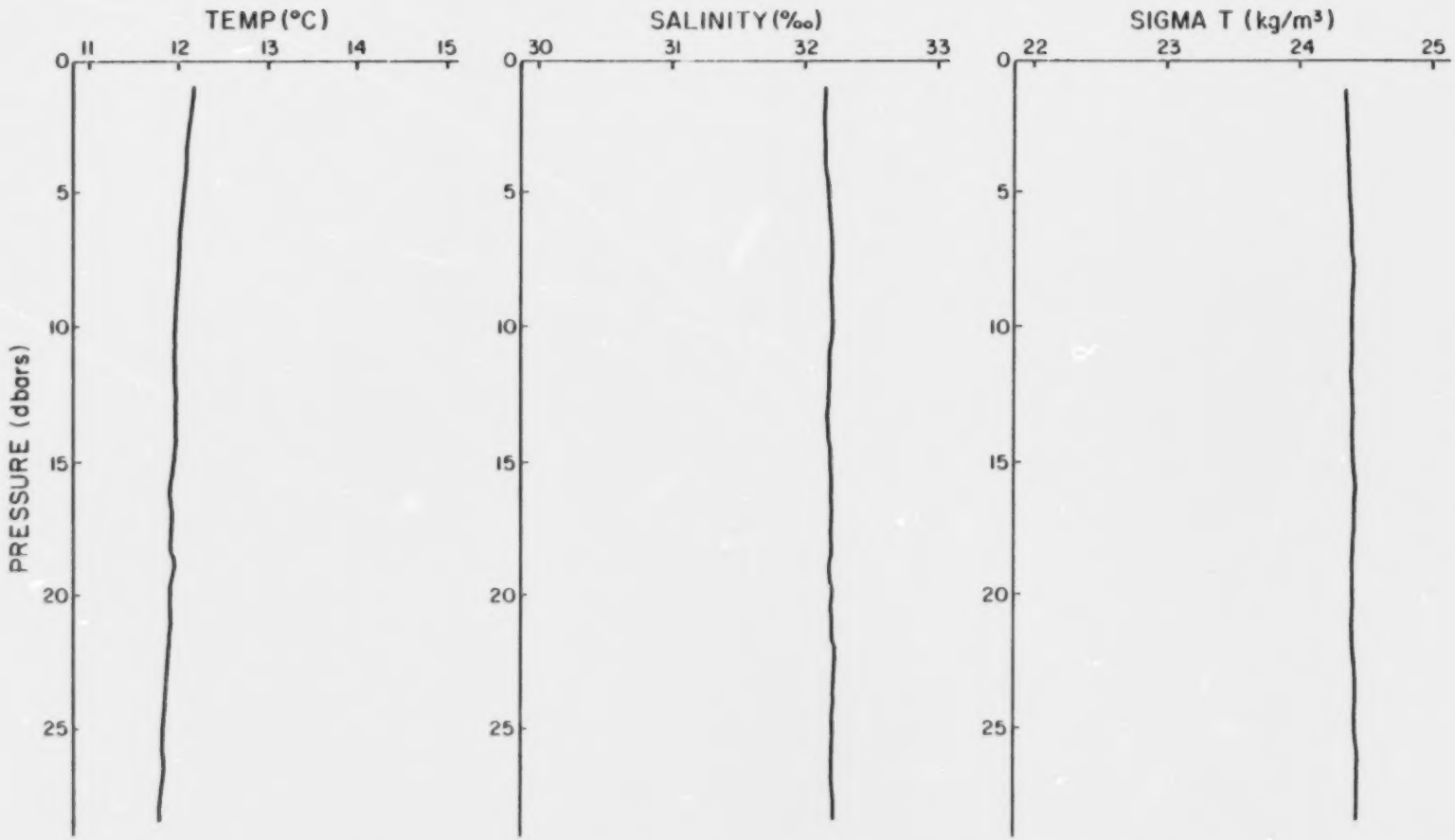

Figure 19. Typical temperature, salinity and density profiles in the area of the outfall, but uneffected by it , during the September survey.

found at the surface which is reflected in the vertical profile of the temperature (Figure 20). Figure 21 shows contours of surface temperature from some of the stations. Elevated temperatures appear at the surface as predicted by MacLaren Atlantic Limited (1977), and measured surface temperature rises of up to 1.9°C are at the low end of their predicted range of 2 to 3°C for a single-unit operation (MacLaren Atlantic Limited, 1977). Again, the affected area is approximately 1 km^2.

During the course of this survey, controlled liquid waste releases were undertaken by the generating station involving tritium at activities ranging from 42 to 508 Bq/l (Table 9). Tritium results from surface and bottom samples collected at CTD stations are exhibited in Figure 22 and Figure 23, respectively. Those samples from Stations 11 through 29 were collected following the releases. Background H-3 levels are characterized by levels 1.5 and 1.9 Bq/l. The highest H-3 levels were measured shortly after the releases began at the station outfall. Tritium levels decreased as a function of time and distance from the outfall.

Figure 24 shows a temperature H-3 mixing diagram for measurements on samples collected throughout the vicinity of the outfall during the three separate releases. During the releases, observations should lie either on the lines shown, based on simple mixing of liquid water with Bay of Fundy water, or at background levels. Also shown on Figure 24 are four observations from stations occupied during the release from tank #1. Although the four observations do not lie on any of the lines shown, the fact that these observations lie on a straight line suggests consistent mixing of the tank water with that in the Bay of Fundy and complete mixing within the tank. However, the implied H-3 concentration at the outfall, determined by extrapolating the line to the outfall temperature of 24.8°C,

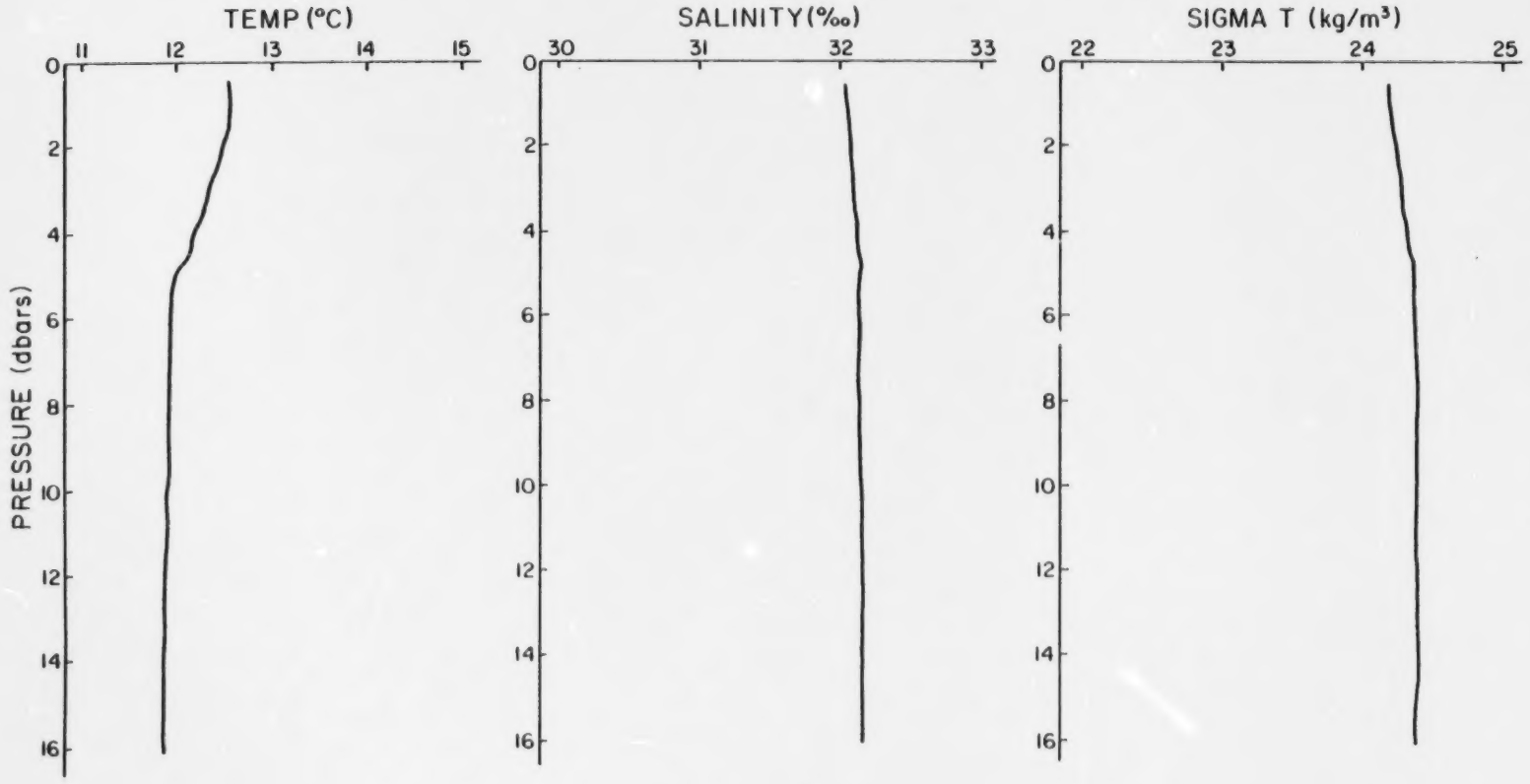

Figure 20. Temperature, salinity and density profiles showing the elevated temperatures at the surface encountered during the September survey.

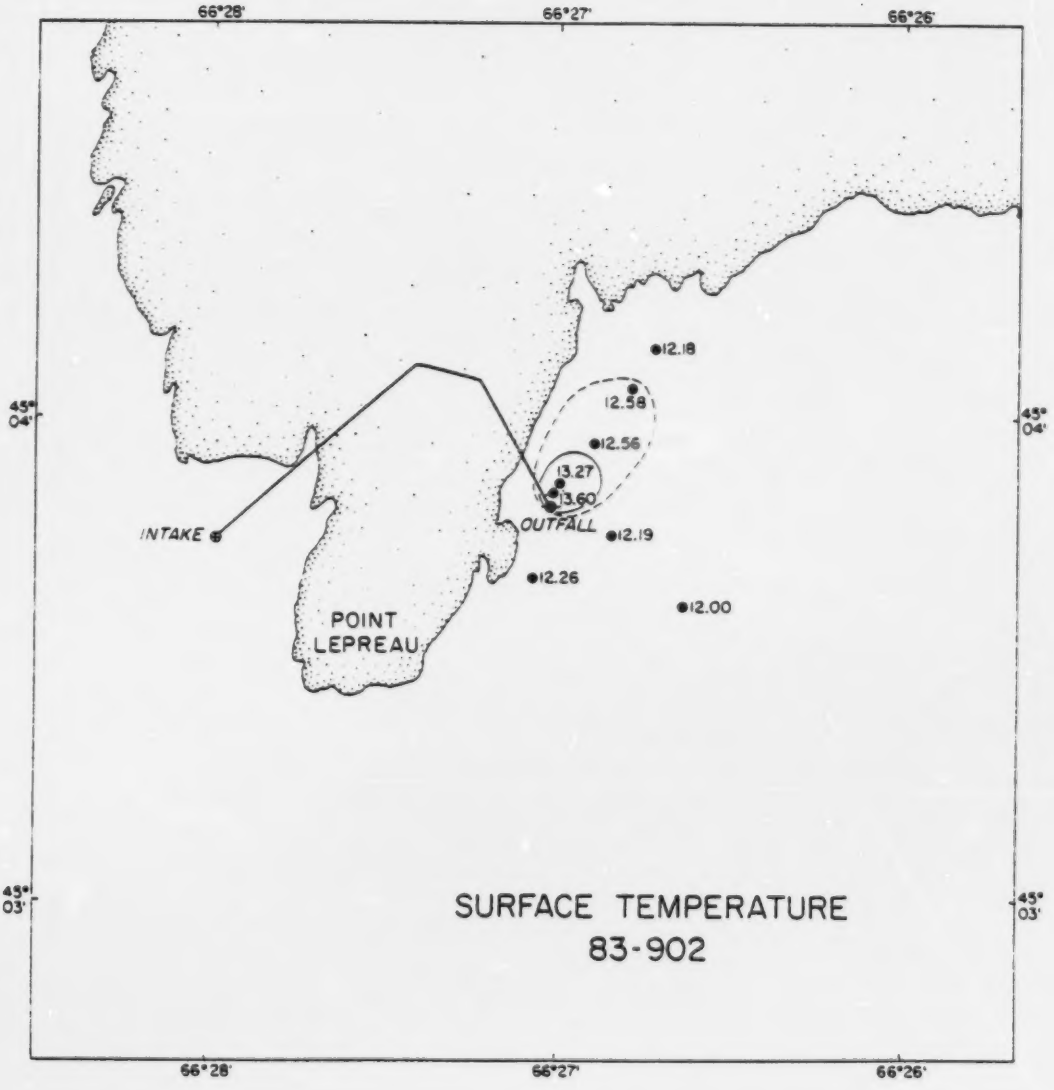

Figure 21. Surface temperature at selected stations during the Septenber survey.

Table 9. Details of liquid waste pumpouts for September 27, 1983 (Jan U. Burnham, personal commmunication).

Tank No.	Time (GMT)	Tank Conc. (Bq/l)	Volume (l)	Outfall Conc. (Bq/l)
1	1400 - 1520	3.24×10^6	2.03×10^4	508
2	1525 - 1555	9.46×10^5	1.84×10^4	358
4	1600 - 1720	2.70×10^5	2.03×10^4	42

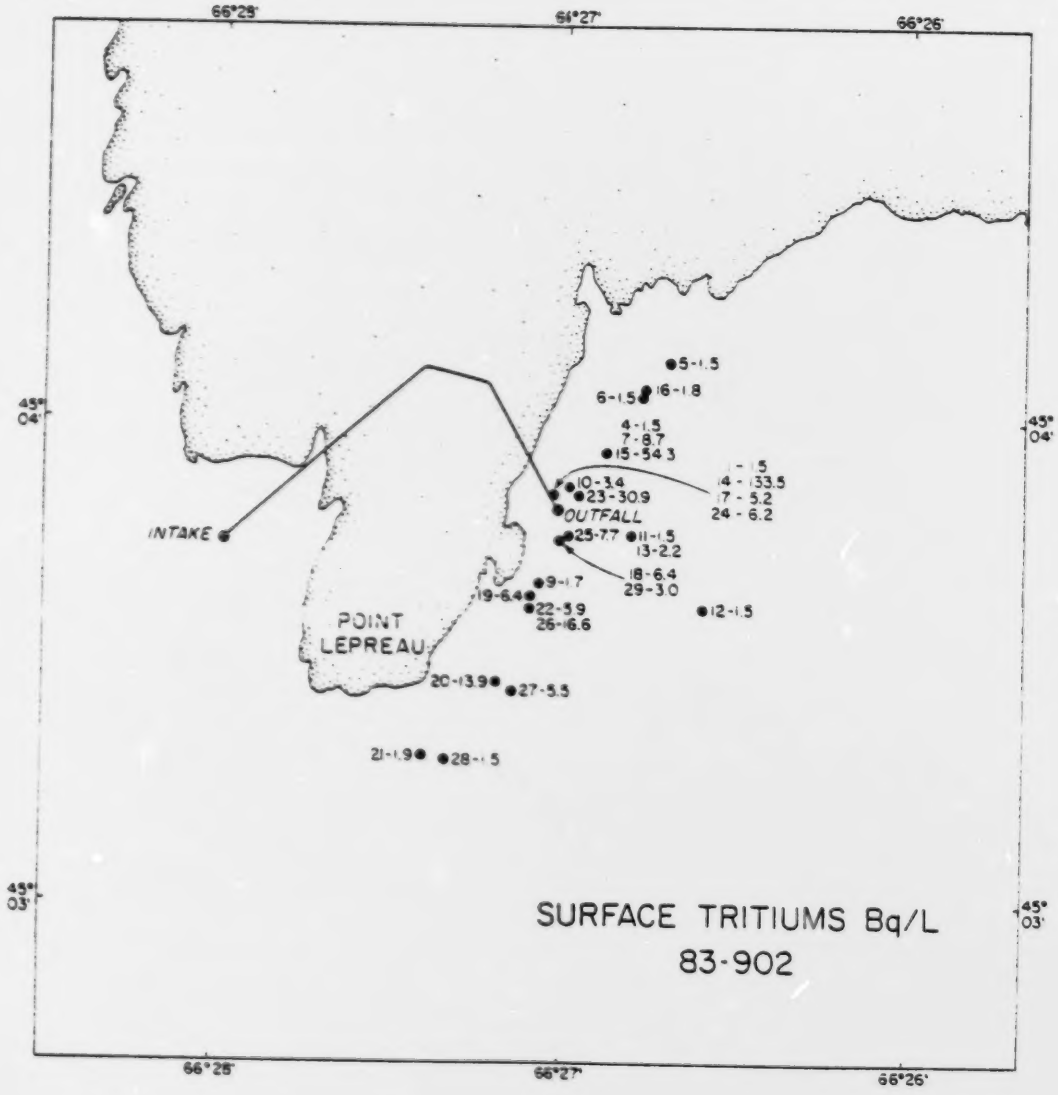

Figure 22. Surface H-3 at CTD stations during the September, 1983 survey.

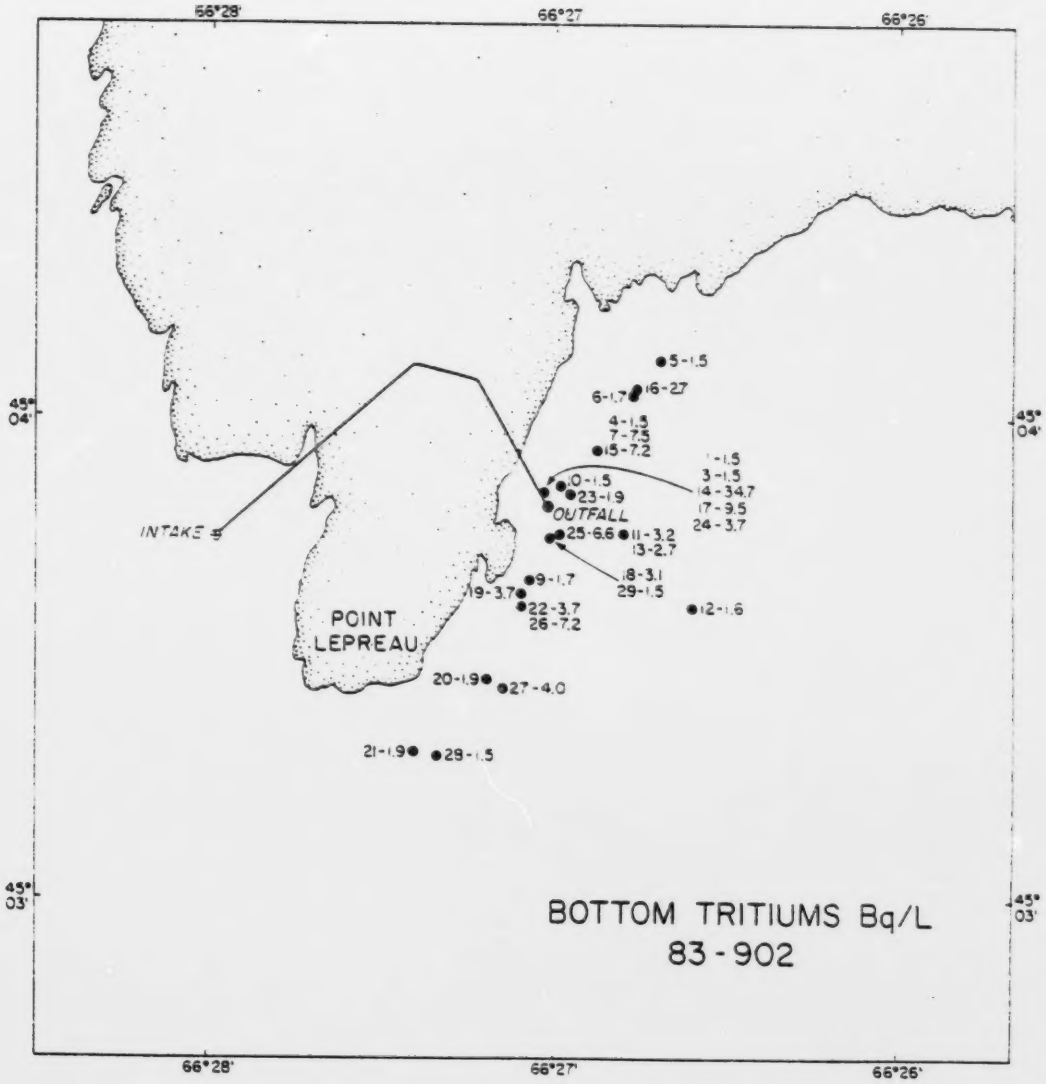

Figure 23. Bottom H-3 at CTD stations during the September, 1983 survey.

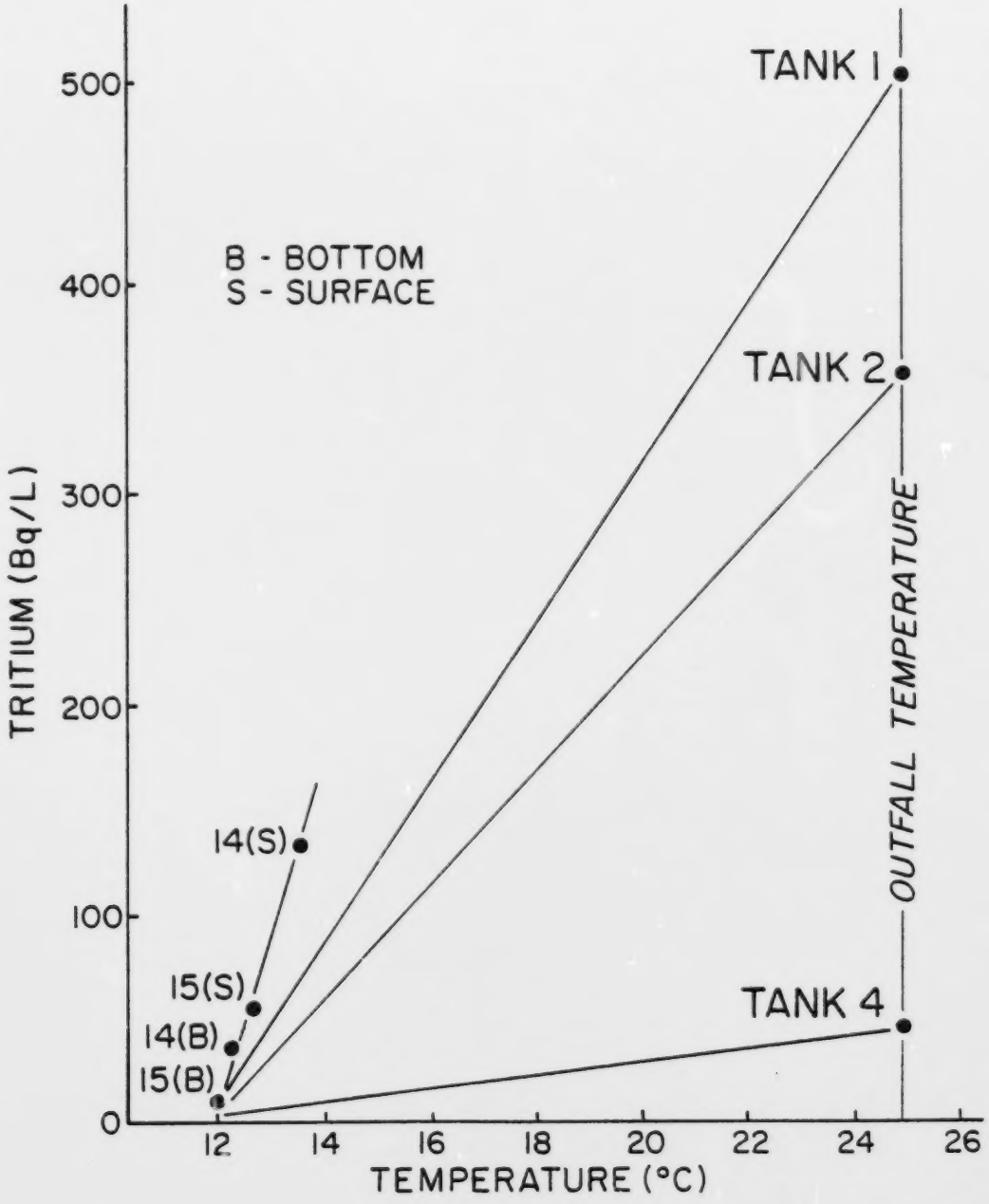

Figure 24. Temperature - H-3 mixing diagram showing ambient Bay of Fundy waters and outfall properties during the waste pumpouts. Also shown are some observations. (see text for explanation).

is either twice that quoted or the temperature is much lower (approximately 17°C). The reason for this discrepancy is unknown but is under investigation.

Figure 25 shows an enlargement of the lower left portion of Figure 24 for surface observations during the various releases. The samples are represented by a symbol that corresponds to the particular release occurring at the time the sample was taken. Samples taken during the first release had levels of tritium either at the detection limit (Stations 12, 13, 16, 17, 18, and 19) or well above the expected activity as discussed earlier (Stations 14 and 15). After the first release, the picture is rather confusing. During the second pumpout the levels of tritium ranged from greater than expected (Station 23 at 30.9 Bq/l) to the detection limit. During the third release, most samples collected had levels of tritium just slightly higher than expected (Stations 24, 25, 27, 28, and 29). Levels measured at Station 26 correspond exactly to that expected for water pumped out during release #1. The scatter and deviation from predicted levels is not unexpected given that the currents near the outfall were in the process of turning from eastward to westward flow making it possible for water from a previous release to be swept by the outfall during another release.

In summary, the April observations indicated that the spring water stratification caused by spring runoff traps the thermal plume at mid-depth resulting in reduced mixing and a higher increase in temperature than expected near the release point. In September when little stratification occurs in the water column, the observations agreed well with those predicted by MacLaren Atlantic Ltd. (1977) where elevated temperatures occur in surface water only, at temperatures of 2°C above ambient levels. The

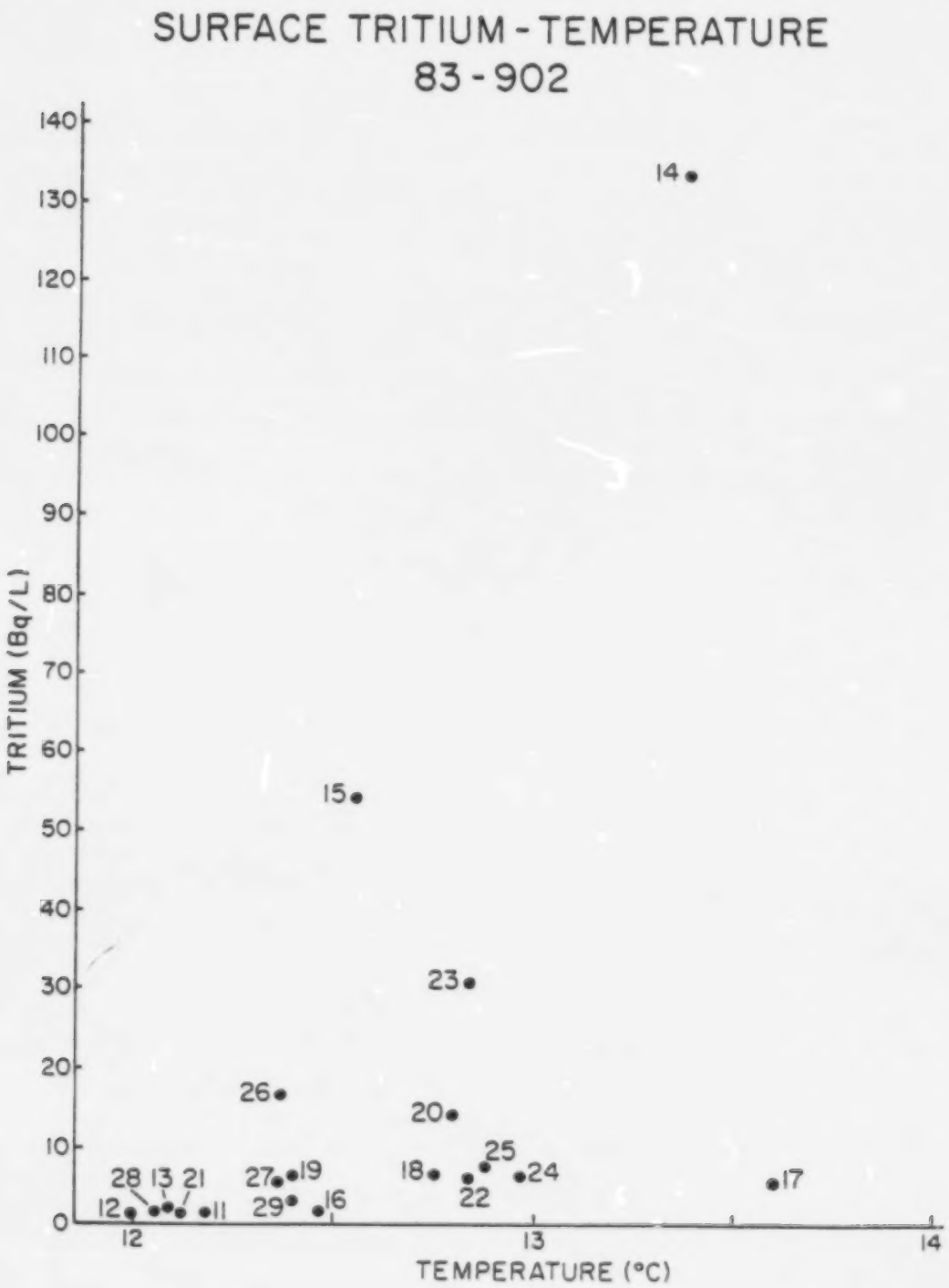

Figure 25. Temperature - H-3 mixing diagram (enlargement of Figure 24) showing surface observations only during pumpouts.

September observations of H-3 levels show a discrepancy between the reported tritium levels in the tanks and the measured tritium levels in the Bay of Fundy. A survey planned for July 1984 may clarify some of these points.

3.0 ATMOSPHERIC MONITORING

The atmosphere is the most dynamic environmental medium for the transport of gaseous and particulate emissions from nuclear power generating facilities. The dispersion of radionuclides released via stack gas emissions follows several pathways; direct deposition, transport via air movement and subsequent exchange with surface water and transfer to various media via precipitation of airborne particulates.

The two principal components of the atmospheric monitoring program at Point Lepreau are (1) the compilation of a meteorological data base for the Point Lepreau region which can be applied in the projection of the transport of airborne pollutants under diverse weather conditions and in atmospheric transport models and (2) the collection of atmospheric water vapour and particulate samples for radionuclide analysis.

3.1 Meteorological Data Collection

Meteorological sensing equipment for measuring temperature, relative humidity, precipitation and wind speeds and directions 10 metres above ground has been in operation for five years at Hall's Lake Siding. In December of 1983 the station was moved approximately 3 km east to the New Brunswick D.O.T. maintenance depot at Musquash, N.B., to facilitate equipment maintenance.

The Atmospheric Environment Service abstracted the temperature, relative humidity and wind data for 1983. The wind speed and direction data is summarized in Table 10. The marked preference for a southwesterly wind direction is evident again in this year's data. Wind speeds are generally higher in the spring and fall with a greater percentage of calm days during summer and winter months.

Table 10. Percent frequency of wind direction and mean speeds from U2A wind sensor at Hall's Lake Siding, N.B. during 1983.

HALL'S LAKE SIDING (POINT LEPREAU), NEW BRUNSWICK, 1983

	Apr - June		July - Sept		Oct - Dec		Annual (9 months) +	
Direction	% Frequency	Mean Speed	% Frequency	Mean Speed	% Frequency	Mean Speed	% Frequency	Mean Speed
N	3.7	8.1	2.7	4.2	5.8	5.6	4.1	6.1
NNE	5.5	10.1	1.6	5.0	4.6	5.8	4.0	7.8
NE	4.1	6.8	2.0	4.0	2.9	5.0	3.0	5.7
ENE	2.9	5.2	1.6	2.9*	1.5	4.3	2.0	4.5*
E	6.7	6.4	3.2	2.6*	2.1	7.4	4.1	5.9*
ESE	5.5	7.5	1.7	3.3*	1.4	5.5	3.0	6.4*
SE	2.3	6.1	0.6	3.9*	3.5	6.7	2.1	6.3*
SSE	3.3	7.3	1.6	6.6	2.7	8.1	2.5	7.4
S	9.5	5.9	5.8	4.1	3.8	6.6	6.4	5.5
SSW	11.1	5.4	10.7	4.6	7.6	5.5	9.8	5.1
SW	9.3	4.9	11.9	3.9	6.4	4.5	9.2	4.4
WSW	2.3	3.9	2.7	3.5	4.3	5.5	3.1	4.5
W	0.8	3.6	2.7	3.9	9.1	7.0	4.2	6.2
WNW	0.9	3.8	3.2	5.3	6.0	7.7	3.3	6.6
NW	1.7	5.6	3.6	5.9	7.2	8.4	4.1	7.3
NNW	1.5	5.9	3.0	4.6	5.4	5.8	3.3	5.5
CALM	29.1		41.4		25.5		31.7	
ALL DIRECTIONS		4.5		2.5		4.7		3.9

\+ January, February, March missing.
* Wind speed data missing for month of July.

NOTE: Wind speed is in knots. 1 knot equals 1.852 km/hr.

Rainfall data has been collected at both the Musquash station and at Saint John Airport (Table 11). Although the trends are similar there is a marked difference in the rainfall patterns for the two sites, as has been previously observed (Smith et al., 1982).

3.2 Air Monitoring Stations

Four air monitoring stations, previously described in Bishop et al. (1980) and deployed in the Point Lepreau region at the sites indicated in Figure 26, are illustrated schematically in Figure 27. The stations located at the Point Lepreau lighthouse (#3), Dipper Harbour (#2), and Mace's Bay (#4) are situated close to stations owned and operated by the New Brunswick Electric Power Commission's (NBEPC) Nuclear Operations Group and allow for a comparison of data. A fifth station has been located at Digby, N.S., to assess the magnitude of airborne radionuclide transport from Point Lepreau across the Bay of Fundy.

Air samples are drawn through a 47 mm diameter type 'A' glass fibre filter (to remove particulates), a cartridge of activated coconut shell carbon (to remove I-131) and a molecular sieve 'bomb' which absorbs water vapour. Sieve air flow rates are regulated according to estimates of seasonal variation in absolute humidity. This ensures that the water sample collected is within the sieve's retention capacity.

The approximate detection limits, which vary depending on sampling and instrumental parameters, are 4×10^{-5} Bq m^{-3} for particulate Cs-137, 3×10^{-5} Bq m^{-3} for I-131, and 1 to 7×10^{-2} Bq m^{-3} for H-3 in water vapour. These detection limits assume a decay interval between sampling and analysis of 10 days.

Relative humidity and temperature data are available from the

Table 11. Comparison in inches of monthly precipitation at stations located in Saint John and Musquash, New Brunswick.

Month	Saint John	Musquash
January	2.95	5.10
February	2.99	2.10
March	5.55	5.40
April	7.36	7.80
May	8.43	7.30
June	1.69	1.60
July	3.23	3.30
August	4.53	4.20
September	2.56	2.60
October	3.43	3.30
November	7.05	10.10
December	8.03	7.60
Yearly Totals	57.80	60.40

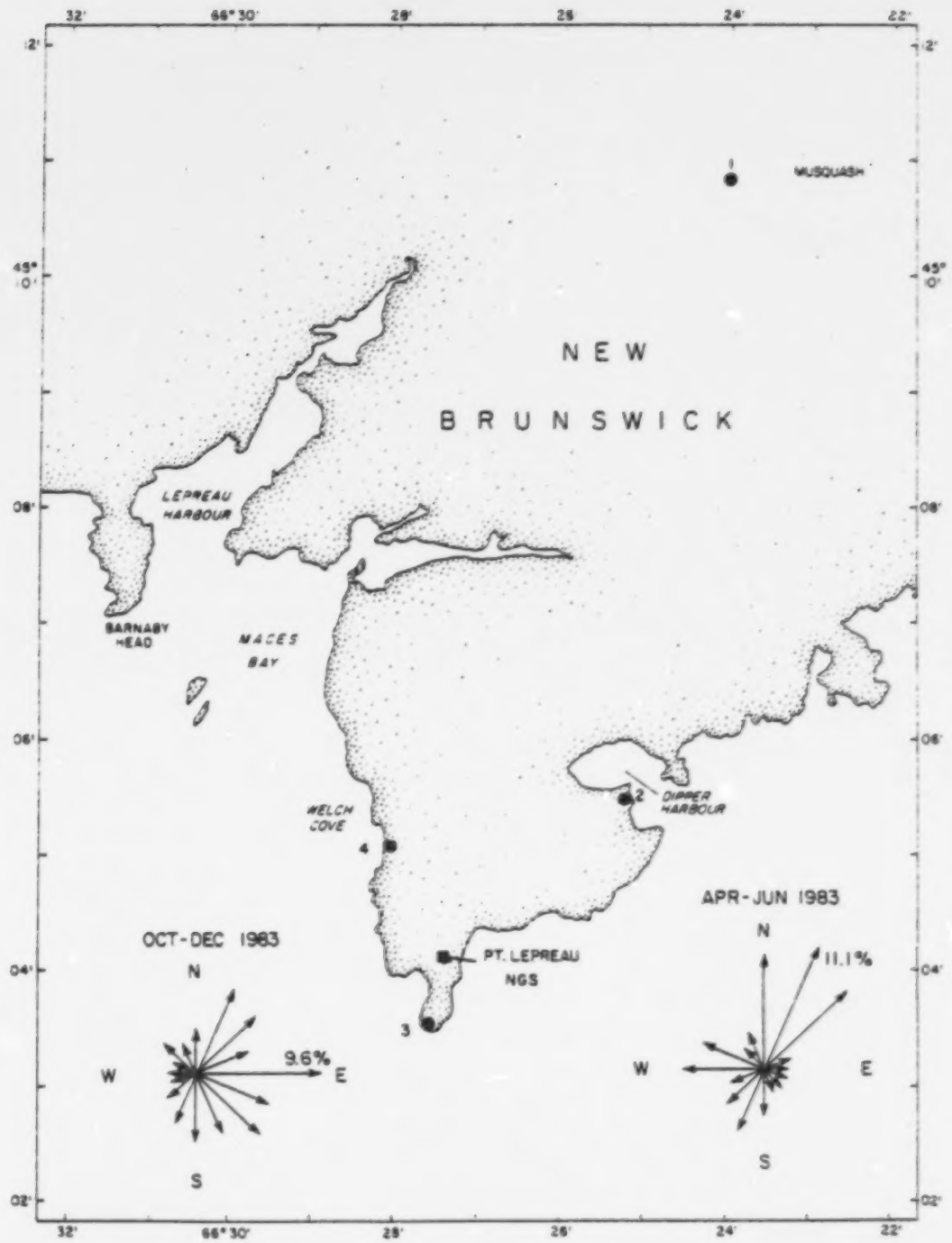

Figure 26. Air monitoring station locations. A fifth air monitoring station is located at Digby, N. S.

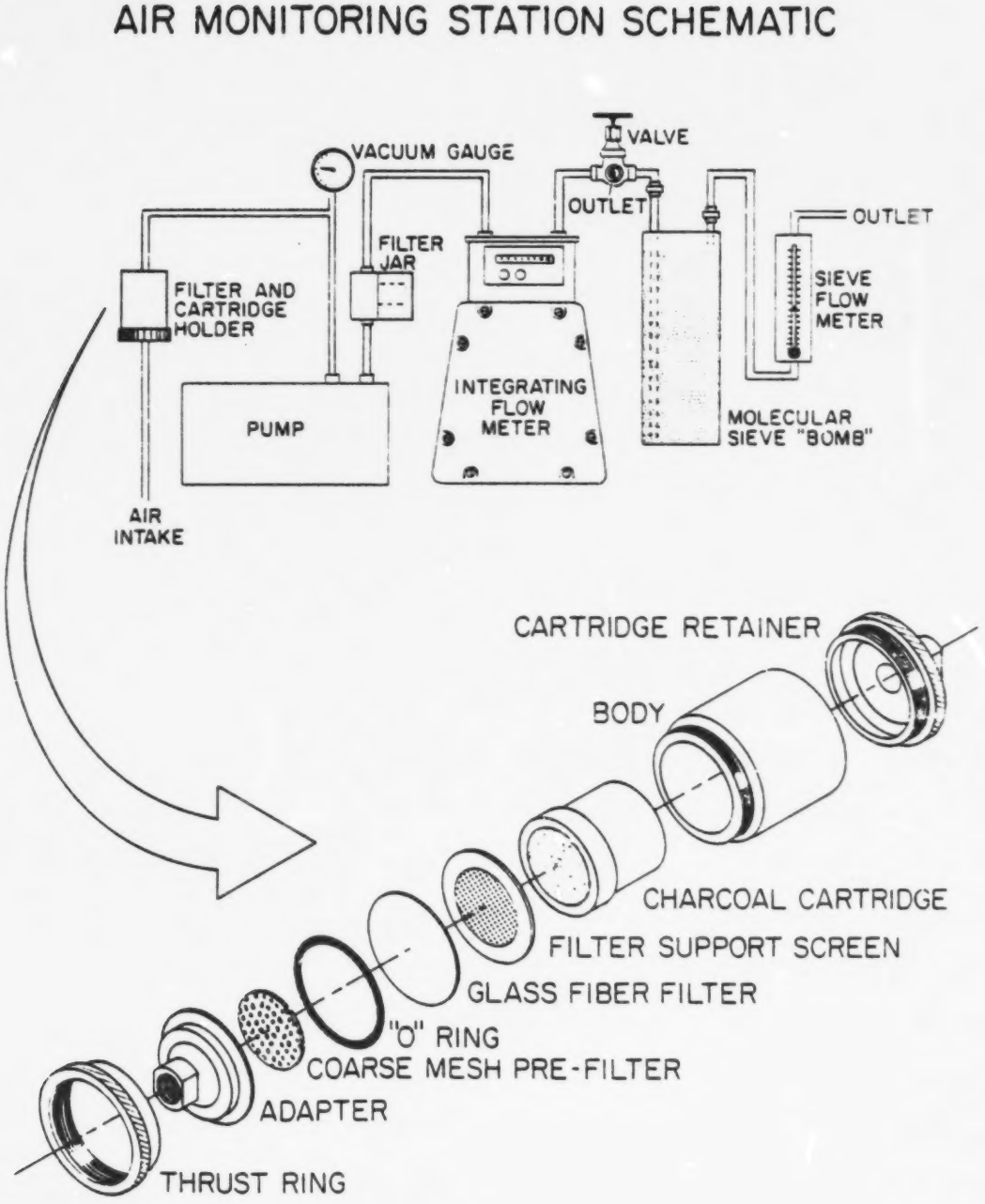

Figure 27. Schematic diagram of air monitoring station used in the field to collect water vapour (on molecular sieve), particulates (glass fiber filter) and I-131 (on charcoal cartridge).

meteorological station at Musquash and are used as a check for absolute humidities calculated from sieve water recovery data (Figure 28). There is excellent agreement between calculated and observed absolute humidities. Absolute humidity increased dramatically during summer months due to increased air temperature.

3.2.1 Tritium Results

The five air monitoring stations have been operating satisfactorily through 1983. Individual sampling periods ranged from 6 to 13 days and an average of 941 cubic meters of air was drawn through the filters. Variations in sample volumes resulted in varying particulate loads and sample periods. Water was distilled from the molecular sieve material and analyzed for tritium following the procedures outlined in Bishop et al. (1980).

The results of tritium measurements for samples collected at the five air monitoring stations are presented in Figures 29, 30, and 31. The error bars represent the two sigma counting uncertainty. Tritium activity is reported both in terms of air volume (Figures 29,31) and in terms of atmospheric moisture (Figure 30).

Tritium activity calculated in terms of air volume is presented in Figure 29 for all five air monitoring stations for 1982 and 1983. Figure 31 gives just the 1983 data for stations # 4 (Lepreau Lighthouse), # 2 (Dipper Harbour) and # 4 (Welch's Cove). Two peaks in tritium activity for 1983 are apparent, one during the summer months (June, July, August) and a second, larger peak, during the winter (November, December). The summer peak in tritium activity has been observed previously (Ellis et al., 1984) and can be related to the summer maxima in absolute humidity shown in

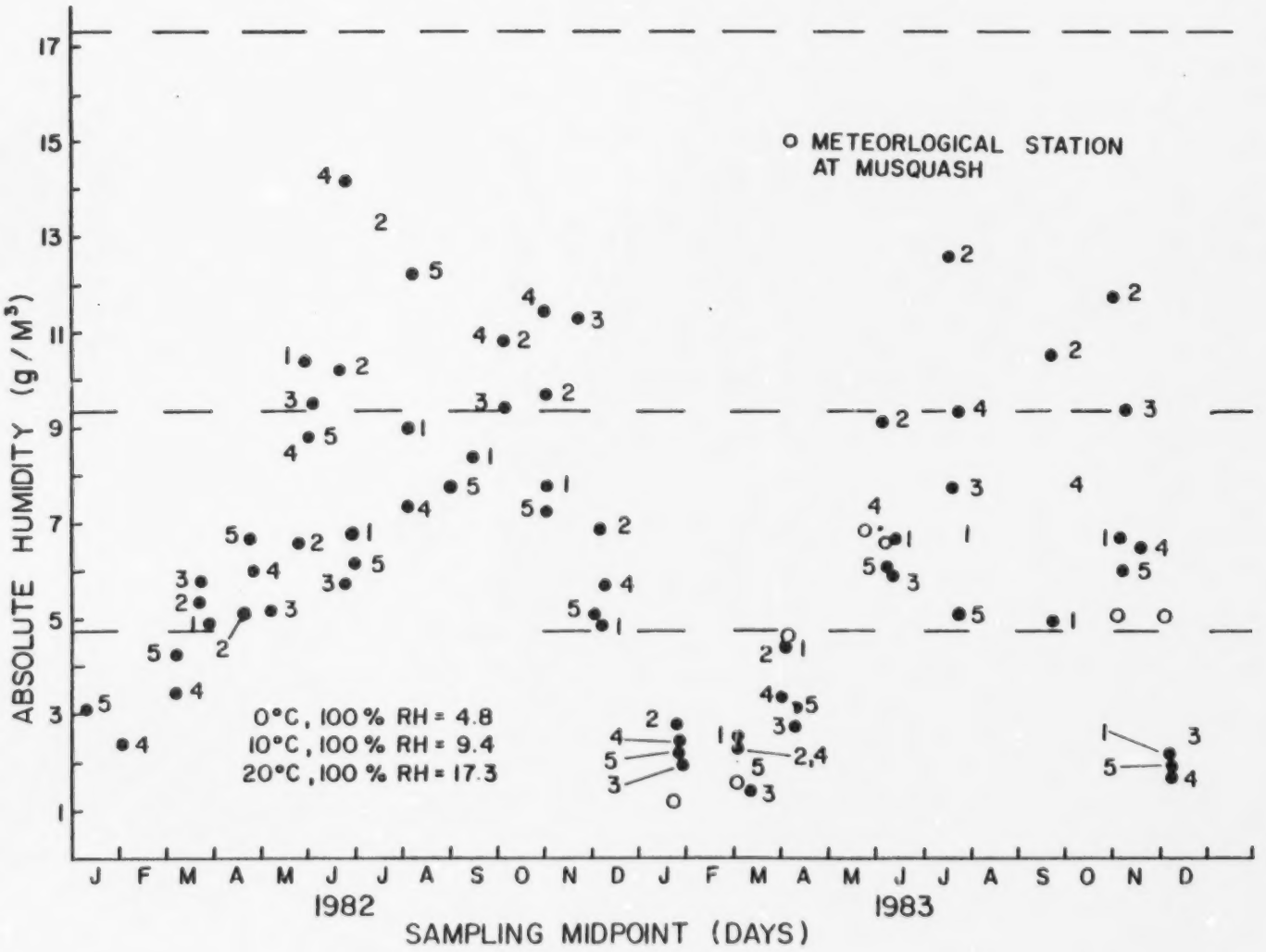

Figure 28. Absolute humidity for the sampling periods corresponding to tritium measurements given in previous figures. Dashed lines correspond to theoretical absolute humidities at the different temperatures.

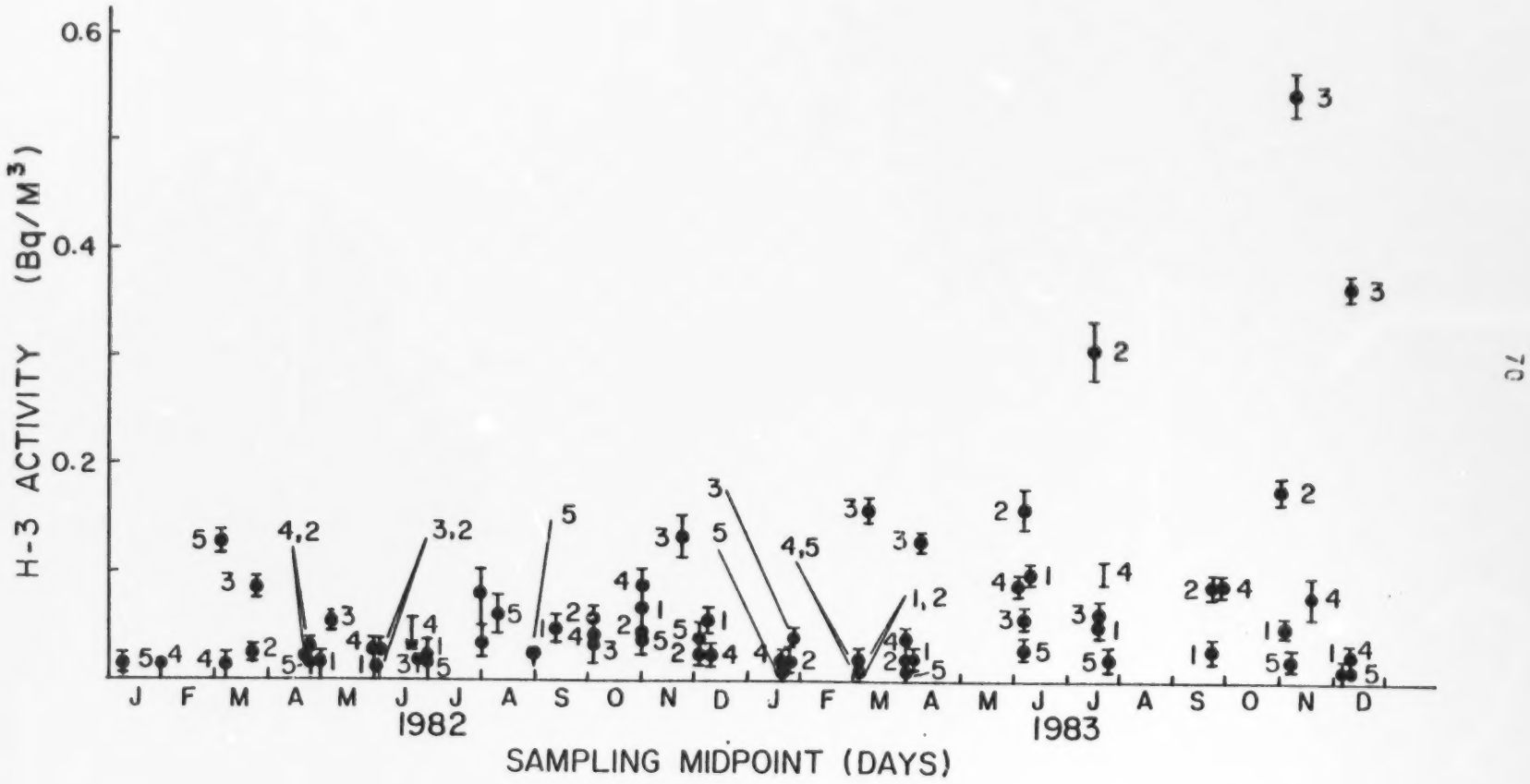

Figure 29. Tritium activities as a function of air volume (Bq/m^3) for different air monitoring stations plotted as a function of sampling date for 1982, 1983.

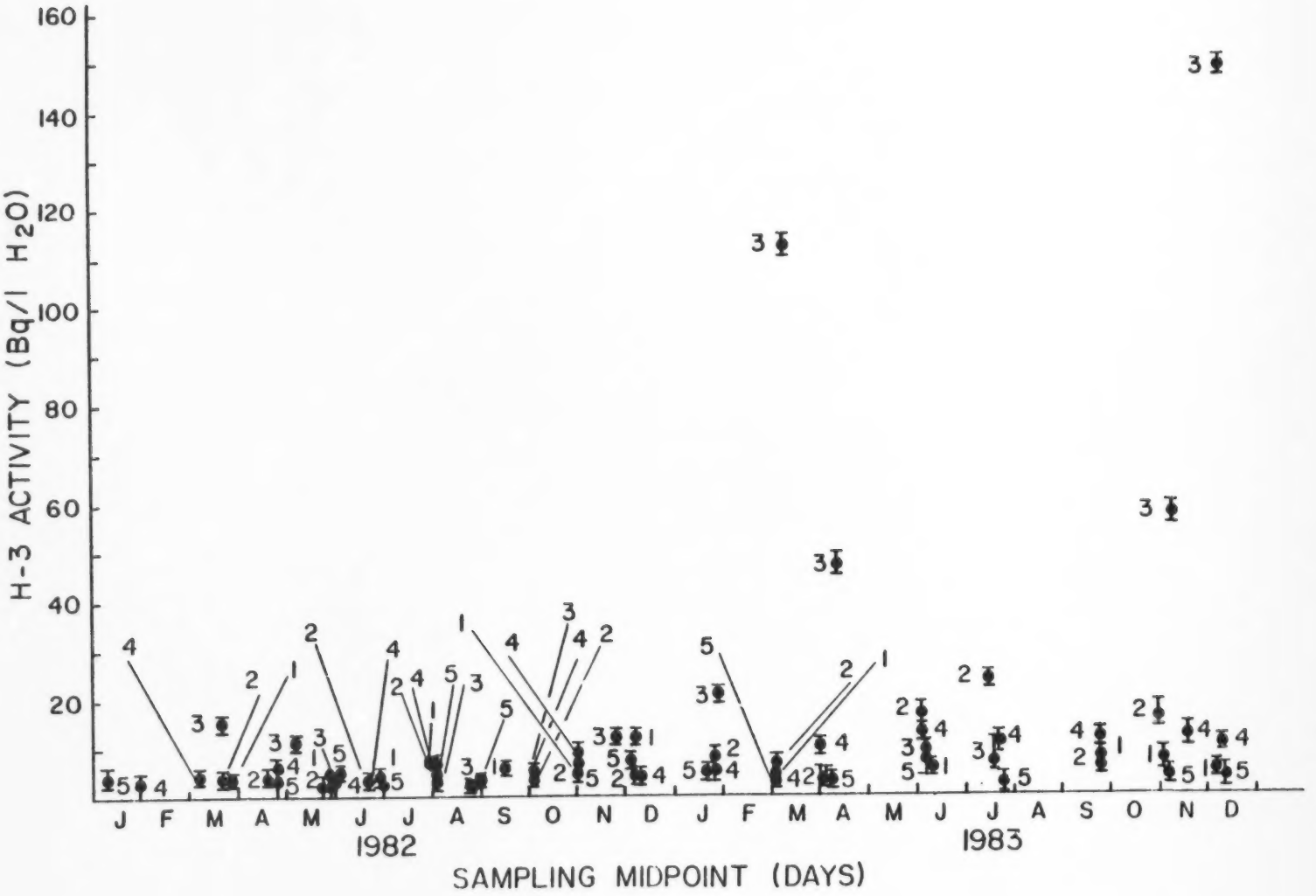

Figure 30. Tritium activities (Bq/l) for different air monitoring stations as a function of sampling date for 1982,1983.

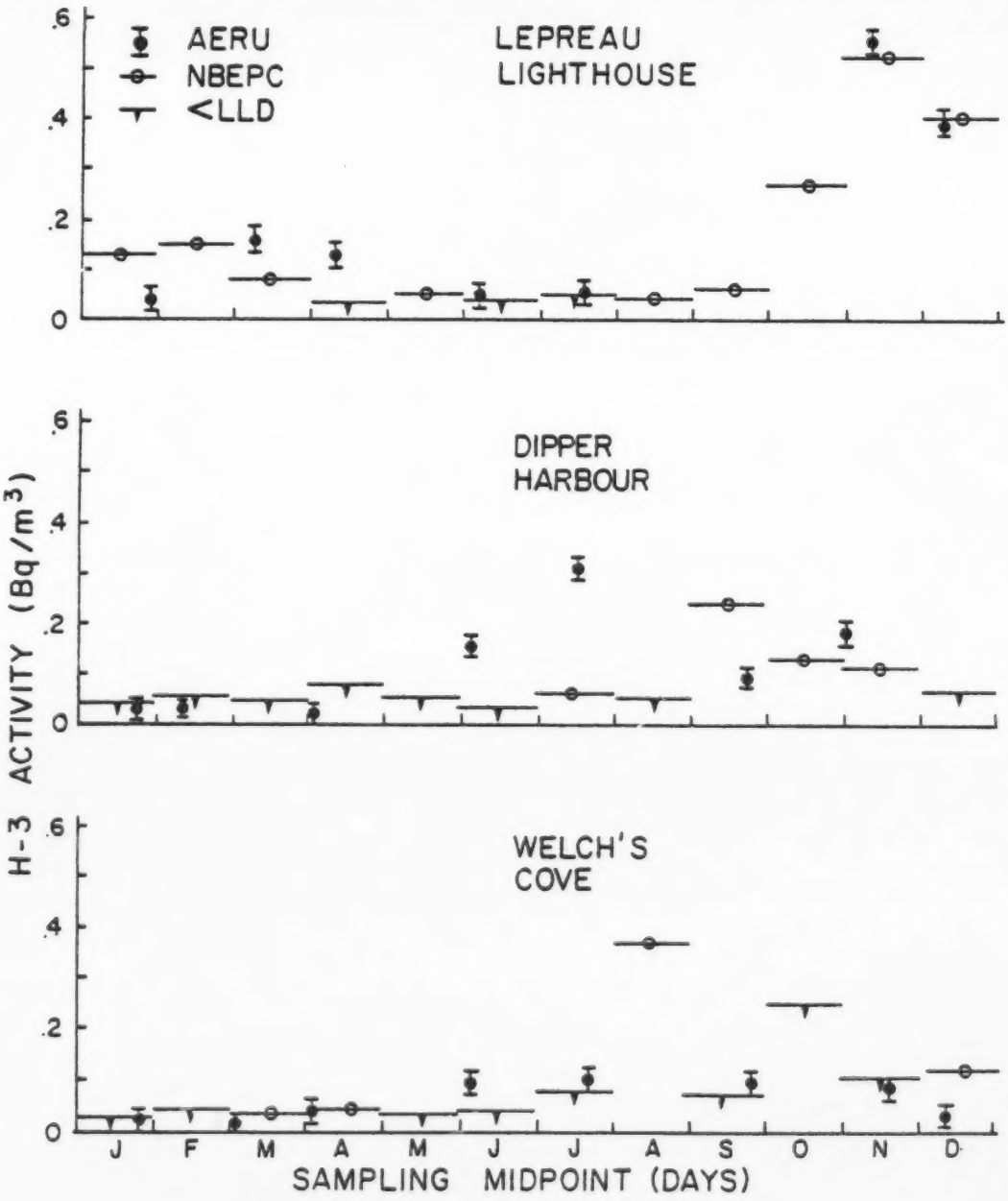

Figure 31. Comparison of tritium activities measured by NBEPC and AERU at equivalent sites.

Figure 28. Figure 30, which shows tritium activity in terms of atmospheric moisture, indicates that not only is the winter tritium maximum a real signal above the baseline level of approximately 5 Bq/l, but that the summer peak in tritium activity is only partly explained by the summer maximum in absolute humidity and a tritium signal above background is readily evident at stations 2 and 3. The average tritium activity measured in 1983 at all air monitoring stations was 18 ±30 Bq/l with a maximum value of 149 ±3 Bq/l. This can be compared to pre-operational tritium levels of 6 ±4 Bq/l in 1981, and 6 ±2 Bq/l in 1982. The highest tritium signals were observed at air monitoring station # 3, located at the tip of Point Lepreau within two kilometers of the NGS, where the maximum value of 149 ± 3 Bq/l was measured and an average of 58 Bq/l was found. Comparison of tritium levels at the two other sites located close to the NGS, Dipper Harbour and Welch's Cove, serve to point out the importance of a sound knowledge of meteorological conditions in the area. The two stations are on opposite sides of the NGS and Dipper Harbour, which is northeast of Point Lepreau, is twice as far away as Welch's Cove. Average tritium levels at both Welch's Cove (10 Bq/l) and Dipper Harbour (12 Bq/l) have increased above the background of 6 Bq/l but while the increase at Welch's Cove is uniform (range of 2 to 13 Bq/l) and within tritium activity levels measured in the pre-operational program (range of <2.5 to 17 Bq/l for 1981 and 1982), fluctuations at Dipper Harbour increased from background levels during the early part of 1983 to peak levels of 24 ±2 Bq/l in July. The increase in tritium activity in the summer at Dipper Harbour can be related to the summer preference for a southwesterly wind direction (Table 10, Figure 26), which transports gaseous emissions from the NGS toward Dipper Harbour and generally away from the Maces Bay (Welch's Cove) area. The wind roses in Figures 26 and

32 clearly show that the prevailing winds in the area consistently blow away from Maces Bay, effectively maintaining the tritium signal close to background levels. A comparison of 1982 and 1983 average tritium activities (Figure 32) clearly indicates that the pattern of the tritium increase around the Point Lepreau NGS compared to those measured during the pre-operational program.

The New Brunswick Electric Power Commission operates a system of seven air-monitoring stations in the Point Lepreau area, three of which are operated adjacent to stations operated by AERU. Figure 31 shows the comparison of NBEPC and AERU results on a station to station basis. NBEPC stations were operated with sampling periods of approximately four weeks duration with twelve to thirteen sampling periods per year. Not all stations were changed at the same time (two each week) so that the periods were not synchronous for all locations. Sample collection consisted of a seven day continuous pumping during which time approximately 600 m^3 of air was sampled (Sutherland et al., 1983). The nature of the sampling programs operated by NBEPC and AERU make direct comparisons difficult. Major tritium peaks observed were generally short term and events could be observed at one station which was operating, but missed by another which was in the process of being changed. Despite these problems, major tritium releases were observed by both programs and the results presented indicate excellent agreement. In general, the major tritium excursions discussed were recorded by each sampling program and agreement was excellent. Differences observed were probably due to non-coincident sampling periods.

The results of the 1983 air monitoring program indicate a definite increase in airborne tritium in the Point Lepreau region and constitutes the first measurable radioactive impact of the operation of the nuclear

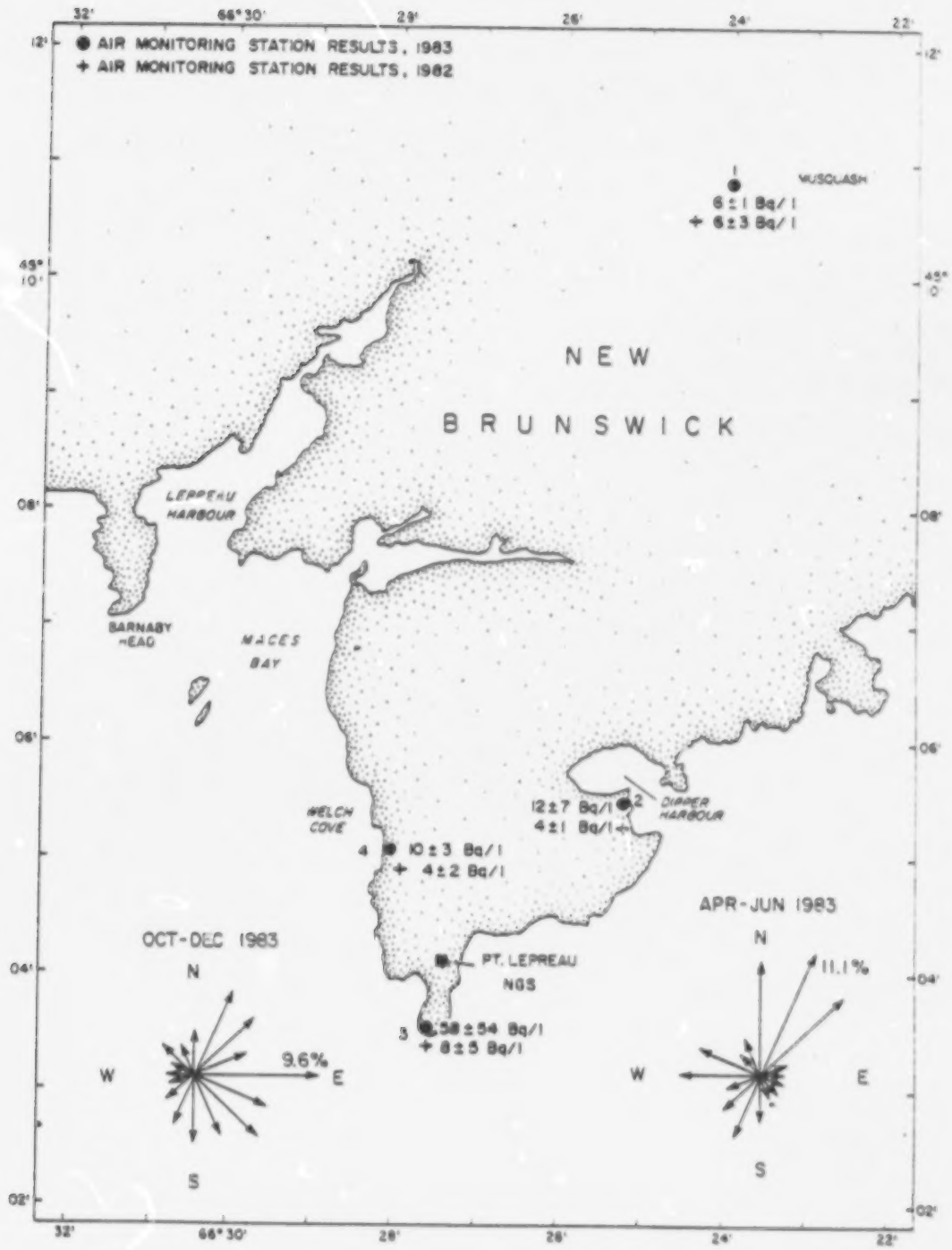

Figure 32. Comparison of tritium activities measured at air monitoring sites located in the Point Lepreau area 1982 and 1983.

generating station. The measurement of an enhanced tritium signal at Dipper Harbour illustrates the importance of meteorological conditions on the dispersion of airborne radionuclides.

3.2.2 Radionuclides in Atmospheric Particulates

Air filters containing airborne particulate matter were analysed for gamma-emitting radionuclides on hyper-pure Ge or Ge(Li) detectors. Results for air filters are presented in Table 12. The station numbers correspond to the locations shown in Figure 26. No radionuclides, with the exception of Be-7, which is a naturally-produced cosmogenic tracer, were detected. Results for airborne particular matter from NBEPC air-monitoring stations were similar to AERU results and the activity of all radionuclides measured (except Be-7) was less than or equal to NBEPC detection limits (Sutherland et al., 1983).

3.2.2.1 Beryllium-7

Beryllium-7 is a naturally-occurring radionuclide which is the product of the cosmic ray fragmentation of atmospheric nitrogen and oxygen which takes place in the upper stratosphere. The atmospheric distribution of Be-7 depends on the source region and the transport mechanisms in effect. Be-7, because of its high specific activity, short half life (53 days), lack of dilution by stable beryllium and its particle affinity has been extensively used to estimate the residence time of aerosols in the upper troposphere. Furthermore, because of its wide distribution in the atmosphere and its particle-reactive characteristics, Be-7 has proven useful as a particle tracer for rapid processes in the marine and aquatic environment (Krishnaswami et al., 1980).

Table 12. Radionuclide results for air particulate material collected on air filters at air-monitoring stations identified by location numbers shown in Figure 23.

Sample No.	Station	Date (Julian)	Volume (m^3)	Radionuclide Activities (mBq/m^3) Cs-137	Be-7
83-01601	1	23	877.8	<0.07	<0.7
83-01602	2	23	756.1	<0.08	0.8 ± 0.8
83-01603	3	28	1376.2	<0.04	1.4 ± 0.4
83-01604	4	24	877.8	<0.04	1.0 ± 0.4
83-01605	5	23	859.1	<0.04	1.5 ± 0.4
83-01606	1	63	739.1	<0.04	1.9 ± 0.1
83-01607	2	63	750.4	<0.04	2.7 ± 0.1
83-01608	3	68	781.5	<0.04	4.2 ± 0.2
83-01609	4	61	790.0	<0.04	3.2 ± 0.2
83-01610	5	60	824.3	-	-
83-01611	1	94	775.9	<0.02	0.6 ± 0.1
83-01612	2	92	747.6	<0.07	2.0 ± 0.2
83-01613	3	100	798.5	<0.04	1.1 ± 0.1
83-01614	4	92	982.6	<0.05	0.8 ± 0.2
83-01615	5	95	876.4	<0.004	0.5 ± 0.1
83-01616	1	157	747.6	<0.05	2.5 ± 0.2
83-01617	2	154	707.9	<0.05	2.1 ± 0.4
83-01618	3	157	611.6	<0.05	2.1 ± 0.2
83-01619	4	154	719.2	<0.05	2.0 ± 0.4
83-01620	5	158	760.3	<0.05	2.0 ± 0.4
83-01621	1	198	824.0	<0.01	3.2 ± 0.1
83-01622	2	196	637.1	<0.1	0.2 ± 0.1
83-01623	3	198	781.5	<0.04	2.3 ± 0.1
83-01624	4	201	716.4	<0.05	2.1 ± 0.1
83-01625	5	203	1029.9	<0.03	1.4 ± 0.1
83-01626	1	262	877.8	<0.04	2.0 ± 0.1
83-01627	2	262	484.2	<0.07	1.4 ± 0.2
83-01628	3	262	583.3	<0.06	1.8 ± 0.2
83-01629	4	264	832.5	<0.04	0.6 ± 0.2
83-01630	5	266	324.4	<0.01	0.6 ± 0.03
83-01639	1	303	852.3	<0.06	1.7 ± 0.2
83-01640	2	301	229.4	<0.1	<1.3
83-01641	3	309	339.8	<0.08	0.8 ± 0.2
83-01642	4	318	826.8	<0.04	1.2 ± 0.1
83-01643	5	305	853.5	<0.03	2.0 ± 0.1
83-01644	1	336	756.0	<0.04	1.9 ± 0.1
83-01645	2	-	-	-	-
83-01646	3	338	484.2	<0.05	0.9 ± 0.1
83-01647	4	340	1390.0	<0.02	0.3 ± 0.05
83-01648	5	338	244.7	<0.1	1.9 ± 0.03

The Be-7 results for 1983 are presented in Figure 33 and Table 12. The range of Be-7 values measured in 1983 was 0.8 to 4.2 mBq/m^3 with an average value of 1.6 mBq/m^3. These values are lower than previous measurements of Be-7 of 0.8 to 5.5 mBq/m^3 (average = 2.5 mBq/m^3) for 1981 and 0.7 to 6.5 mBq/m^3 (average = 2.4 mBq/m^3) for 1982. This decrease in Be-7 air concentration is related to the increase in rainfall which occurs from 1982 to 1983 (36.7 inches to 53.5 inches for March to December). Since the Be-7 air concentration is probably a function of input of Be-7 from the upper atmosphere and the removal of Be-7 to the earth's surface, an increase in rainfall will cause an increase in the removal of Be-7, and therefore cause a decrease in the air concentration of Be-7.

3.2.2.2 Cesium-137

Cesium-137 is a relatively long-lived ($t_{1/2}$ = 30.2 yr) fission product whose primary input to the environment is from nuclear weapons testing that has occurred over the last quarter of a century. Cs-137 and Sr-90 are the two fallout radionuclides that contribute most of the fallout exposure to present generations. They are produced in similar quantities during nuclear tests with a mean Cs-137/Sr-90 ratio of 1.5 and fallout activity values for one nuclide can be estimated from measurements of the other. Figure 34 shows the quarterly fallout record for Sr-90 for New York city as measured by Environmental Measurements Laboratory (EML, 1984). The results indicate that fission product inputs are declining from a peak value in the early 60's to the low levels present today. The smaller peaks evident in the 1970's are the result of tests carried out by India, France and China. The Cs-137 results for 1983 are presented in Table 12. In all cases Cs-137 activities are below AERU detection limits.

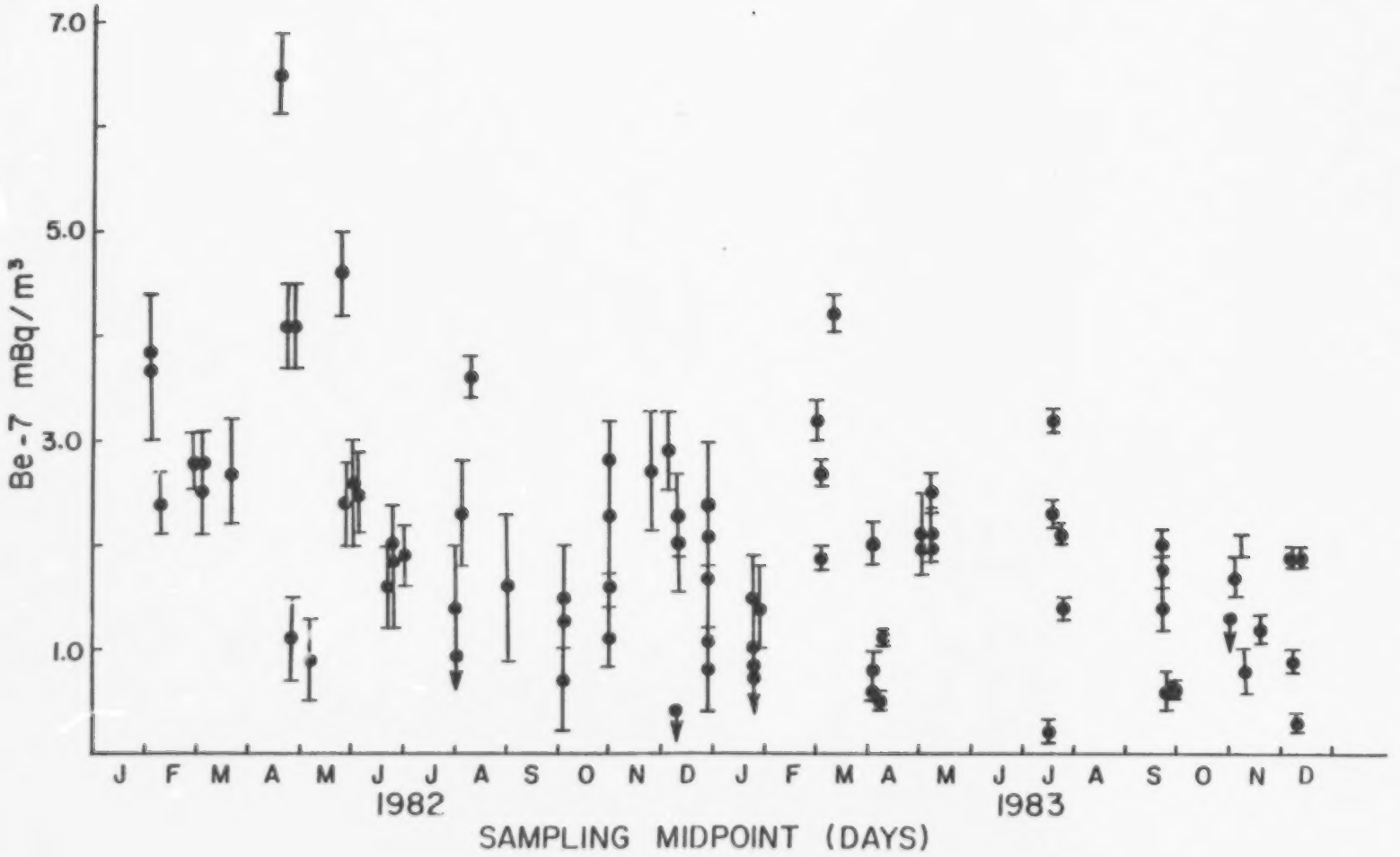

Figure 33. Be-7 activity measured in air particulate material for 1982 and 1983.

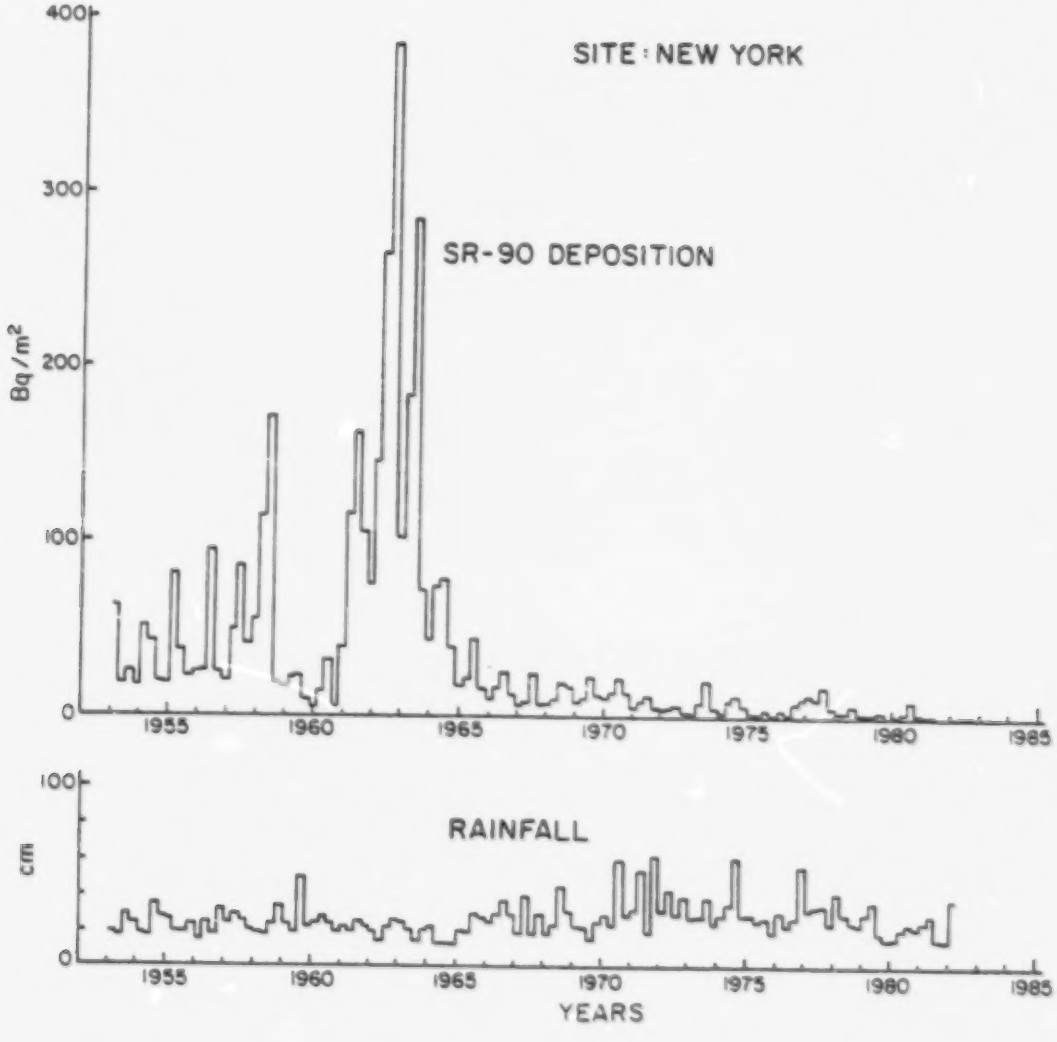

Figure 34. Quarterly fallout record of Sr-90 for New York City measured by Environmental Measurements Laboratory (1983).

4.0 BIOLOGICAL OCEANOGRAPHY

One of the principal concerns associated with the operation of the Point Lepreau NGS is the effect of the releases of radioactivity and waste heat on biological phases of the marine environment. The release of radioactivity into the marine environment from a nuclear generating station is effectively a point source input that can lead to relatively high concentrations of activity in localized areas. However, the overall extent of the contamination is usually confined and the activity is only rarely distinguishable from background at distances greater than a few hundred kilometers from the point of discharge.

The major elements of seawater, chlorine, sodium, magnesium, etc. are referred to as conservative, i.e. their concentration is proportional to the salinity. The oceans, however, are not homogeneous with regard to chemical composition since other components in seawater such as nitrogen, phosphorus, and iron are involved in biological cycles and vary in both geographical and seasonal distributions. Coastal waters are even less homogeneous as a result of the influence of freshwater runoff, circulation patterns which favor the retention of dissolved chemical species in the waters near the coast, and heterogeneously distributed biological activity. Therefore, the degree of dispersion of radionuclides released into coastal waters will depend upon the physical characteristics of the receiving water mass and the chemical properties of the element. Radionuclides released into the marine environment are subject to a variety of influences. They can remain in solution or in suspension, precipitate and settle to the bottom or be assimilated by plants and animals. Phenomena such as currents, turbulent diffusion, isotopic dilution and biological transport act to dilute and disperse radionuclides. Simultaneously, chemical and physical

forces such as absorption, ion exchange, flocculation and sedimentation and the passage of radionuclides from primary trophic levels up through the food chain can act as concentrating mechanisms (Rice et al., 1974).

4.1 Biological Uptake of Radioactivity

The availability of radionuclides to marine organisms depends on the chemical and physical properties of the radionuclide and on complex interactions involving environmental and biological factors. With the exception of tritium, most of the radionuclides released from nuclear generating stations are non-conservative elements (i.e., they do not directly follow water circulation patterns) and their biological uptake is generally higher than that of conservative elements. Marine organisms can accumulate and redistribute radionuclides independently of other physicochemical processes resulting in the potential 'concentration' of radio-activity throughout different levels of the food chain. The term concentration factor (C.F.) has been used to describe the biological uptake of a chemical species and is defined as the activity of the nuclide per unit fresh weight of the organism divided by the activity of the same nuclide per unit volume of water (Coughtrey et al., 1983).

$$C.F. = (100 - \%\ H_2O)\ A_{Cs-137}\ \text{sample}/100\ A_{Cs-137}\ \text{water}$$

where % H_2O is the percent water per sample wet weight, A_{Cs-137} sample is the Cs-137 activity in the sample dry weight, and A_{Cs-137} water is the mean Cs-137 activity in sea water (in our case, the mean sea water Cs-137 activity of 3.3 mBq/l in the lower Bay of Fundy). Concentration factors defined in this manner are of limited value for higher trophic levels where

organisms ingest radionuclides from a variety of sources and for infaunal marine organisms which ingest large amounts of sediment along with organic detritus. Despite these deficiencies, concentration factors do provide a semi-quantitative description of radionuclide accumulation in the marine environment.

Biological half-life is another concept useful in describing the uptake of radionuclides in marine systems. The biological half-life is defined as the time required for an organism to exchange half its total inventory of an element. The shorter the biological half-life, the faster an organism will reach a steady state with respect to seawater radionuclide concentrations. This concept is important in water masses where radionuclide activities vary as a function of time, such as with releases from nuclear installations. Higher trophic levels with long biological half-lives may never attain a steady state radionuclide concentration with respect to a changing environmental concentration. Conversely, primary producers, such as plankton, often have turnover rates on the order of hours and effectively mirror changing environmental levels.

A third factor which plays an important role in understanding the biological uptake of radioactivity is the physico-chemical interactions that take place between radionuclides and marine organisms. Goldberg (1957) showed that the ability of marine organisms to concentrate metals from the sea paralleled the order of the strength of metal-organo-ligand complexes and Szaba (1967) observed that mixed plankton accumulated alkaline earths in the same sequence as cation exchangers such as Dowex -50. Alkali metals (K, Na, Ru, and Cs) may be incorporated into bottom sediments as the result of ion-exchange reactions with clay minerals and it has been proposed that similar ion-exchange reactions may occur at the surfaces of

marine organisms. More recently, the presence of specific metal binding proteins such as metallothionein, a low molecular weight, sulfur containing metal-binding protein has been correlated with elevated levels of trace metals in marine invertebrates such as oysters, blue crab and lobster (Engel et al., 1984). Metallothionein acts to bind trace metals and remove them from circulation to storage in various organs. In mammals for example, cadmium-metallothionein complexes are stored in the kidney (Ridlington et al., 1981). These proteins have been viewed as inducible (i.e., synthesized in response to the presence of toxic metals, Cherian et al., 1978) and play an important role in the sequestration of elevated levels of trace metals in various organisms.

4.2 Processing and Analysis of Biological Materials

An assessment of environmental effects associated with the biological uptake of radioactivity requires a surveillance program consistent with local and regional marine energetics, the nature of the food web, water circulation and zones of productivity. Sampling sites have been chosen for the collection of representative species as outlined in Table 13. Biological samples have been collected from the major marine habitats in the Point Lepreau region and these samples have been analysed for radioactivity in the AERU laboratory. In general, species which have been selected for surveillance occur abundantly in most of the major habitats and play a significant role in the food web. All trophic levels are represented and any trends in the transport and accumulation of radioactivity within these communities should become apparent at some level within the sampling assemblage. Sampling methods, criteria and frequency have been noted in Bishop et al. (1980), although these procedures have been modified to some extent.

Table 13. Representative species for different marine sampling regimes near Point Lepreau.

SPECIES	EMBAYMENT, ESTUARY	INTERTIDAL ZONE	SUBTIDAL ZONE	PELAGIC ZONE
Plants		Rockweed, Irish moss dulse, Fucus	Laminaria	
Grazers	Periwinkle			
Detritus Feeders		Gammarus		
Suspension Feeders	Soft shelled clams	Blue Mussel	Horse Mussel Scallop	
Predators and Scavengers	Sandshrimp	Green crab Hermit Crab	Rock Crab	Rock Crab
Fish		Flounder		Herring
Birds	Purple sandpiper	Eider Duck	Cormorant, Herring Gull	
Mammals			Harbour Seal	
Planktonic Forms				Bulk Samples Phyto- and Zooplankton

The processing of marine biological samples has been described previously (Ellis et al., 1984). The tritium content of marine biological samples, terrestrial samples and soils was determined using an azeotropic distillation method (Moghissi et al., 1973). Freeze-dried, homogenized samples were analysed for gamma-emitting radionuclides using two 25% efficient high purity germanium detectors. A gamma spectra for each sample was automatically analysed using a PDP-11-04 computer which identified and quantified radionuclide peaks of interest. Samples were analysed using one of five standard counting geometries, corresponding to sample volumes of 500 ml, 300 ml, 100 ml, 50 ml and 20 ml. Detection limits (Bq/kg) for each radionuclide of interest are given in Appendices 3 and 4 for the five counting geometries. A more detailed discussion of AERU counting procedures is given in Ellis et al. (1984).

4.3 Radionuclide Results - Plankton

Plankton occupy a critical position at the base of the food chain. Their rapid growth rates and large surface area make plankton an excellent fast-response indicator species for changes in radioactivity levels in sea water. Phytoplankton are primary producers that accumulate radionuclides by both adsorption which is the predominant mechanisim and absorption which is particularily important for essential trace elements. Zooplankton accumulate radionuclides by both processes as well as consumption of phytoplankton. In the contaminated waters of the Adriatic sea (Jelisaveic, 1970) and near Cap de la Hague, France (Germain et al., 1979) plankton have been shown to accumulate Ce-141,144, Ru-106 and Zr-95 at levels up to 3500 Bq/kg. Elevated levels of Cs-137, Co-60, Zn-65, Sb-125, Fe-59 and Mn-54 were also observed. Levels of radionuclides in zooplankton are generally

lower than those in phytoplankton owing to their relatively inefficient assimilation of radionuclides across the gut wall (Smith et al., 1981).

Plankton samples were collected using plankton net tows along transects shown in Figure 35, using plankton nets which were of 64 µm mesh size (operationally defined) for phytoplankton and 333 µm mesh size (operationally defined) for zooplankton. One plankton sample of mixed phytoplankton and zooplankton was collected and analysed in 1983 for gamma-emitting radionuclides (Table 14) and all radionuclides were below AERU detection limits (Cs-137 = <0.63 Bq/kg; Co-60 = <0.86 Bq/kg). In the pre-operational program one plankton sample out of the 22 samples analysed had a detectable level of Cs-137 (2.3 ±1.8 Bq/kg).

4.4 Marine Algae

Marine algae are primary producers located at the base of the food web. Benthic algae are coated with a mucus (the chemical form differs from species to species) that provides a slippery surface to minimize wear and tear and help prevent water loss during exposure at low tide. The coating also provides an excellent surface for the adsorption of a large range of radionuclides and the concentrations of radionuclides in algae frequently exceed those of the surrounding water (Pentreath, 1980). This factor combined with their sessile nature make benthic algae an excellent site specific monitor for marine radioactivity and trace elements. The degree of accumulation of radionuclides varies from species to species but most are suitable as indicators of radioactive releases to the marine environment.

Marine plants selected as monitoring species at the Point Lepreau NGS include the brown algae; Ascophyllum nodosum, Fucus vesiculosis and Laminaria sp. and the red algae; Chondrus crispus and Rhodymenia palmata.

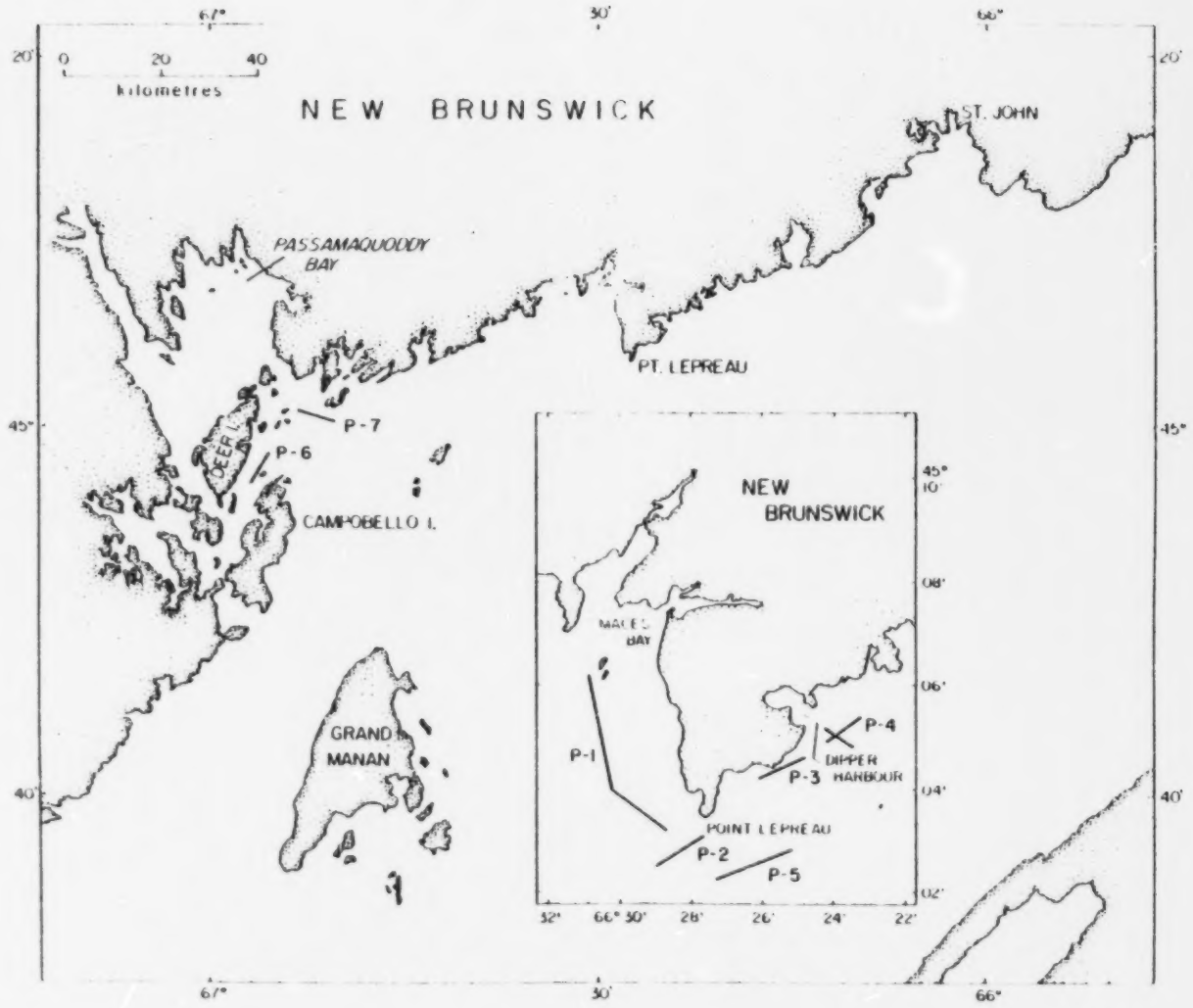

Figure 35. Transects corresponding to sampling tows for Plankton.

Table 14. Radionuclide results for plankton and marine plant samples collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	$\%H_2O$	Cs-137 (Bq/kg)	Range
Plankton	1980-82	Total, n=9	P-1-P-7	-	-	-	96.6	2.3 ± 1.8	< 1.0 to 2.3 ± 1.8
	83-1633	Total	-	7-7-83	247.98	1	-	< 0.63	
Rockweed *Ascophyllum nodosum*	1980-1982	Total	I-4,6,8	-	-	-	74.7	0.4 ± 0.1	0.3 ± 0.1 to 0.5 ± 0.4
	83-1632	Total	I-6	12-9-83	154.67	1	75.8	< 0.8	
	83-9242	Total	S-6	30-9-83	202.46	1	68.5	< 0.3	
Fucus vesiculosus	1981-82	Total	I-6	-	-	-	77.4	0.3 ± 0.1	0.2 ± 0.1 to 0.4 ± 0.4
	83-1631	Total	I-6	12-9-83	106.60	1	78.4	< 1.5	
	83-9243	Total	S-6	30-9-83	120.88	1	78.8	< 0.7	
Kelp *Laminaria Sp.*	1980-82	Total	I-2,3,6,9	-	-	-	80.5	0.9 ± 0.5	0.5 ± 0.3 to 1.2 ± 0.7
	83-1663	Total	I-6	30-9-83	88.72	1	-	< 1.3	
Ulva lacta	83-1659	Total	I-6*	28-9-83	12.73	3	87.7	< 6	

* Sample taken from marker buoy at the cooling water outfall.

The results for marine algae samples collected in 1983, collected at site locations indicated in Figure 36 are presented in Table 14. In all cases values are at comparable levels to those found for samples analyzed in the pre-operational program. Higher levels of radionuclides found in samples collected in 1981 (Smith et al. 1982), including the radionuclides Zr-95 and Mn-54, were from fallout from the October, 1980 Chinese nuclear test and have decayed to levels below AERU detection limits.

4.5 Marine Molluscs

Bivalve molluscs are largely filter-feeders that display a remarkable ability to concentrate a wide range of radionuclides. Radionuclides are concentrated directly from seawater, by ingestion of contaminated food and by ingestion of contaminated silt particles or detritus. Digestion can occur both intracellularly, within the cells of the distal tubules, and extrocellularly within the stomach. Radionuclides are generally stored in the hepatopancreas (Schelske, 1973) but other organs, such as kidneys may specifically accumulate certain radionuclides. Scallops (Pecten maximus) concentrate manganese in the kidney, oysters concentrate zinc and mussels selectively concentrate iron over manganese and zinc. The iron in mussels is particularly highly concentrated in the hepatopancreas but appears to be excreted through the production of byssus threads (Pentreath 1980).

The results for gamma-emitting radionuclides in molluscs collected at sites shown in Figure 36, are given in Table 15. Only Cs-137 and Co-60 were detected in pre-operational samples and those radionuclides were present at levels very close to the detection limit. Radionuclide levels found in 1983 samples were below AERU detection limits.

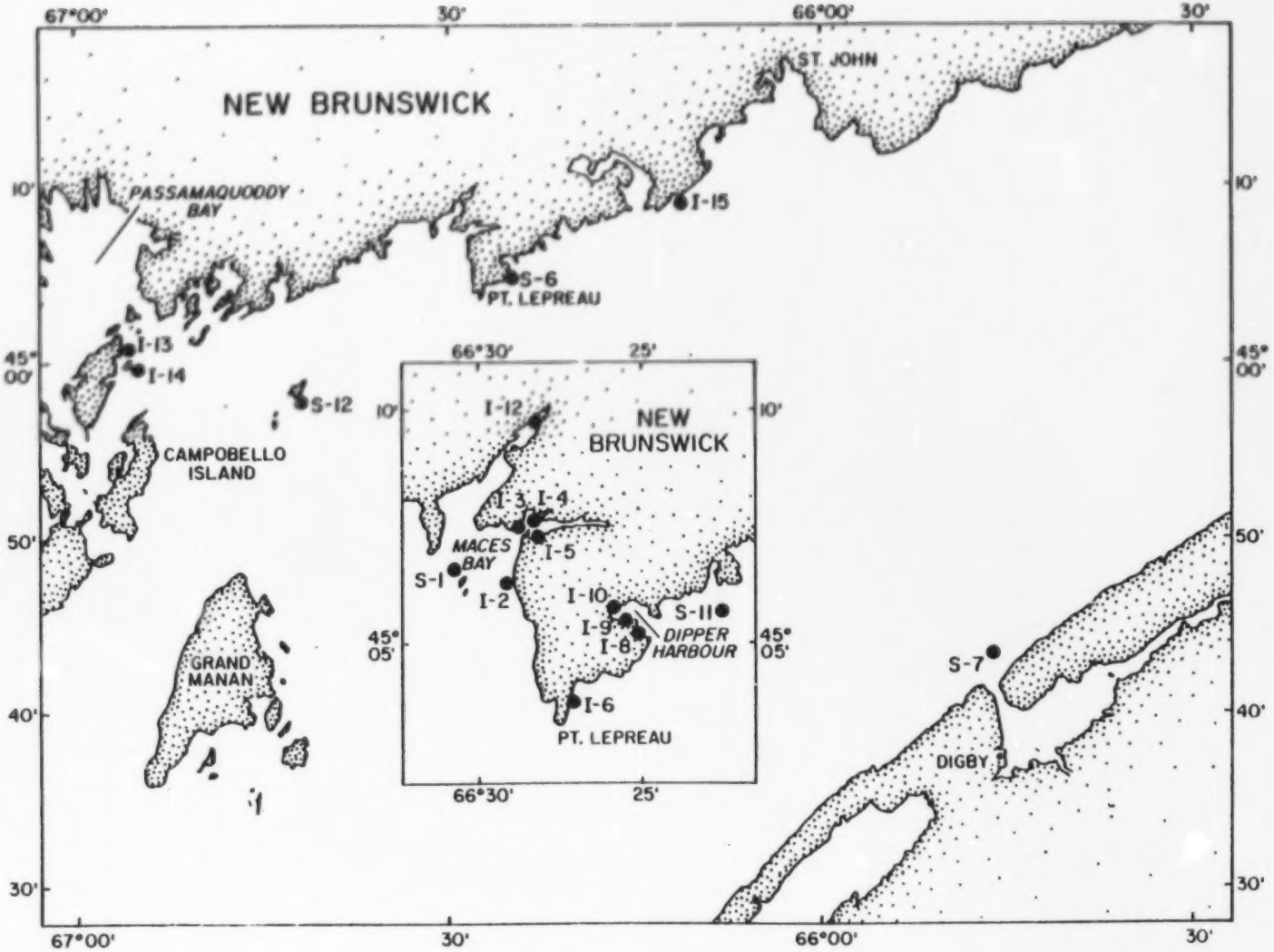

Figure 36. Marine biological sampling sites in the Bay of Fundy.

Table 15. Radionuclide results for marine molluscs and marine crustacea collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	$\%H_2O$	Cs-137 (Bq/kg)	Range (Cs-137)
Horse muscle	1980-82	Flesh	S-1, I-8,6	-	-	-	77.0	1.7 ± 1.2	<1.0 to 1.7 ± 1.2
Modiolus modiolus	1980-82	Shell	S-1, I-8,6	-	-	-	18.8	0.12 ± 0.07	0.07 ± 0.05 to 0.17 ± 0.15
	83-1635	Flesh	I-6	12-09-83	18.96	4	85.4	< 3	
	83-1636	Shell	I-6	12-09-83	549.01	1	13.2	< 0.2	
Periwinkle	1981-82	Flesh	I-6	-	-	-	75.4	< 2.6	
Littorina littorea	1981-82	Shell	I-6	-	-	-	3.7	< 0.2	
	83-1637	Flesh	I-6	12-09-83	54.2	3	64.5	< 1	
	83-1638	Shell	I-6	12-09-83	409.43	1	4.8	< 0.3	
Green crab	1980-81	Flesh	I-6, I-8	-	-	-	69.2	< 6	
Carinus sp.	1980-81	Shell	I-6, I-8	-	-	-	60.2	< 3	
	1980-81	hepatopancreas	I-6, I-8	-	-	-	74.6	<10	
	1982	Total	I-8	14-10-82	71.3	2	71.5	< 2	
	83-1634	Total	I-6	12-09-83	234.38	1	70.1	< 0.8	
	83-9244	Shell	I-6	23-09-83	197.42	1	63.3	< 0.2	
Lobster	83-9224	hepatopancreas	S-6	22-06-83	200.41	1	54.8	< 0.5	
Homarus Americanus	83-9225	"	S-7	22-06-83	129.07	1	56.8	< 0.7	
Sandshrimp	1980	Total	I-3	17-09-80	56.1	2	59.6	0.8 ± 0.5	
Crangon sp.	83-9247	Total	I-6	14-09-83	69.19	1	79.4	< 1.1	

4.6 Marine Crustacea

Benthic crustacea, such as crabs and lobsters, also display a remarkable ability to concentrate certain elements. In crustaceans, most of the absorption from food takes place in the midgut and normally the digestive diverticula are not a primary store for radionuclides. Moreover, the exoskeleton, which often forms a secondary store, is moulted at various periods during the life-cycle and this process can represent a significant route for the transfer of accumulated activity back to the environment if the exoskeleton is not consumed by the animal (Coughtrey, 1982). Crustaceans form an important part of the decomposition cycle in marine habitats with many representatives in the decomposer fauna.

The crustacea selected for use in the Point Lepreau monitoring program include Carcinus maenas, the green crab; Cancer sp., rock crab; Pagurus sp., hermit crab; Crangon septemspinosus, sandshrimp; and Gammarus oceanicus, amphipods. The hepatopancreas from the Homarus americanus, the lobster, has been added to the monitoring program. Samples were collected from Dipper Harbour and off the coast of Nova Scotia, at Digby.

The levels of gamma-emitting radionuclides detected in samples collected in 1983 from locations indicated in Figure 36 were all below AERU detection limits (Table 15). Cs-137 levels measured in the hepatopancreas of lobster were below AERU detection limits as was generally found for Cs-137 levels in other crustaceans during the pre-operational program. Cs-137 was detected in several crustacean samples during the pre-operational program but levels were close to or at AERU detection limits.

4.7 Marine Vertebrates

In general, marine vertebrates are less suitable as indicator species because of their mobility and their inefficient accumulation of radionuclides compared to other organisms. But, because of their commercial importance and their vital position in the food web relative to man, marine vertebrates remain important monitoring species. The primary route for nutrient uptake in fish is through the mouth, with a subsidary route occurring through the gills. The uptake of radionuclides through outer body surfaces is minimal because they are generally impermeable to ions. The accumulation of radionuclides in marine fish is dependent on size (the rate of intake decreases with increasing body size), excretion rates and growth rate.

Marine vertebrates selected for monitoring near Point Lepreau include the following: harbour seal, Phoca vitulina; harbour porpoise, Phocoena phocoena, when available; Pleudopleuronectes americanus, the winter flounder; and Clupea harengus, the atlantic herring.

The pre-operational levels of radionuclides found in marine vertebrate samples were low and the results indicate that there is no apparent increase in activity with increasing trophic level. Results for samples of herring and flounder collected in 1983 are presented in Table 16. No radionuclide activities were found above AERU detection limits.

4.8 Tritium in Marine Organisms

It is generally believed that tritium freely exchanges with hydrogen and that the bio-concentration of tritium is negligible in marine organisms. However, studies on natural ecosystems have revealed levels of tritium incorporated into organic matter at concentrations 20 times higher

Table 16. Radionuclide results for marine vertebrates collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	$\%H_2O$	Cs-137 (Bq/kg)	Range
Herring *Clupea harengus*	1980	Total	S-12	30-10-80	-	-	-	1.1	1.0 ± 0.7 to 1.2 ± 0.5
	83-9251	Flesh	S- 7	19-10-83	66.64	2	67.6	< 4	
Winter flounder *Pseudopleuronectes americanus*	1980	Flesh, n=1	S-11	3-10-83	45.2	2	72.9	< 1.5	
	1982	Flesh, n=1	I- 6	14-10-82	118.08	1	79.4	1.0 ± 0.2	
	1982	Remains, n=1	I- 6	14-10-82	136.18	1	76.6	0.4 ± 0.1	
	1982	Skin, n=1	I- 6	14-10-82	39.59	2	75.6	< 1.9	
	83-9248	Skin	S- 7	23- 9-83	86.93	1	76.3	< 0.9	
	83-9249	Flesh	S- 7	23- 9-83	124.52	1	81.1	< 0.7	
	83-9250	Remains	S- 7	23- 9-83	70.40	1	77.3	< 1.5	

than those in the surrounding water (IAEA, 1981). These seemingly anomalously high levels were due to the presence of tritiated organic compounds in the effluent that were readily absorbed and only slowly exchanged with tritium in the environment (IAEA, 1981).

Most of the tritium released from nuclear reactors is in two forms: molecular tritium gas, released to the atmosphere via stack gas discharges and tritiated water (HTO) both in vapor and liquid form. Molecular tritium is converted into HTO by either exchange or oxidative reactions. The HTO interacts with living organisms via two pathways - exposure of organisms to water contaminated with HTO and the ingestion by organisms of foods contaminated with tritium.

Tritium incorporated by marine and aquatic organisms can exist as tissue-free water and tissue-bound water (i.e. incorporated into organic molecules) and incorporation is dependent on the physico-chemical state of the tritium in the liquid effluent. Tritiated water, HTO, is exchanged with free tissue water very quickly and can represent up to 95% of the tritium in the organism (IAEA, 1981). As well, tritium can be incorporated into organic compounds by the exchange reaction with hydrogen in organic compounds. This fraction consists of two components, a rapidly exchanged fraction with a biological half-life on the order of hours or days and a slowly exchangeable fraction with a $t_{1/2}$ on the order of 300 days (IAEA, 1981). Thus, it would appear that the physico-chemical state of the tritium is a sensitive parameter of particular importance for predicting and evaluating the environmental behavior of tritium.

The effects of tritium incorporation on plants and animals results from mass difference, beta-particle emission or the properties of the decay product He-3, which differ vastly from the properties of hydrogen. Vig

and McFarlane (1972) have identified genetic effects in soybean plants when the seeds were germinated in water containing as little as 370 Bq/ml of tritium.

Tritium levels found in marine systems near the Point Lepreau NGS are given in Table 17. As mentioned previously, AERU reduced the size of its sampling program for the initial year of reactor operation. Two samples of marine algae were sampled at the cooling water outfall and both had levels of tritium approximately twice that found for marine algae in previous years. An average activity of 5.2 Bq/l was found in the 1983 algae samples as compared to an average activity of 2.9 Bq/l for algae samples collected in 1982. This increase in activity may reflect the increased tritium concentration in the immediate vicinity of the reactor outfall, where the 1983 samples were collected.

The sample of crustacea shell material analyzed was found to contain a high level of tritium (7.1 Bq/l) as was observed in previous years (Ellis et al., 1984). The concentration factor calculated to be 2.8 is comparable to results from 1982 when shell C.F.s were found to range from 1.9 to 2.7. The high tritium activity found in shell material is a recurring phenomena that is under investigation.

Table 17. Tritium levels found in marine systems

Species	Sample No.	Site No.	H-3 Bq/l	Concentration Factor
Water	1982	-	avg. 2.31 Bq/l	-
Water	1983	-	avg. 2.53 Bq/l	-
Algae	1982	-	2.3 ± 1.8 to 3.2 ± 1.6 avg. 2.9 ± 0.5	1.0 to 1.4 avg 1.2
Fucus Vesiculosus	83-1631	I-6	4.3 ± 1.7	1.7
Ascophyllum Nodosum	83-1632	I-6	6.1 ± 1.9	2.4
Crustacea	flesh 1982	-	2.4 ± 1.7	1.0
	shell 1982	-	6.3 ± 1.8	2.7
Littorina littorea	shell 83-1638	I-6	7.1 ± 1.9	2.8

* Concentration factor based on the tritium seawater concentration for 1982 or 1983

5.0 TERRESTRIAL AND AQUATIC ENVIRONMENTAL PHASES

The complex interrelationship between the terrestrial and aquatic environmental phases is illustrated in Figure 37. Radionuclides are injected into the system via two primary pathways: (1) the atmosphere, from stack discharges at nuclear generating stations and from above ground nuclear tests, and (2) from effluent releases in the cooling water outflow. In both cases, molecular and turbulent diffusion processes take effect immediately and generally act to reduce radionuclide concentration as a function of distance from the source. At the same time, the radionuclides are subject to depositional phenomena, including gravitational settling, precipitation scavenging, impaction, chemical adsorption and exchange. The high particle reactivity of some radionuclides leads to their rapid removal from the air-water continuum and plays an important role in their subsequent availability for biological uptake.

Radionuclides in the abiotic phases of the environment can enter the food chain at any trophic level. Plants, which are at the base of the grazing food chain, accumulate radionuclides from the soil, from atmospheric deposition, and by sorption from water. At higher trophic levels, mechanisms such as the inhalation of aerosol particles can play an important role for some insoluble radionuclides, as well as the standard plant-herbivore-carnivore cycles.

Ultimately, radionuclides tend to accumulate in 'sinks' composed of deeper strata of soils, sediments and their associated deposits of organic detritus where radionuclides are tightly bound and have negligible contact with biological components. The environmental distribution of radioactivity is as much a function of physiological partioning within the biotic compartments as it is a function of the physical and chemical interactions

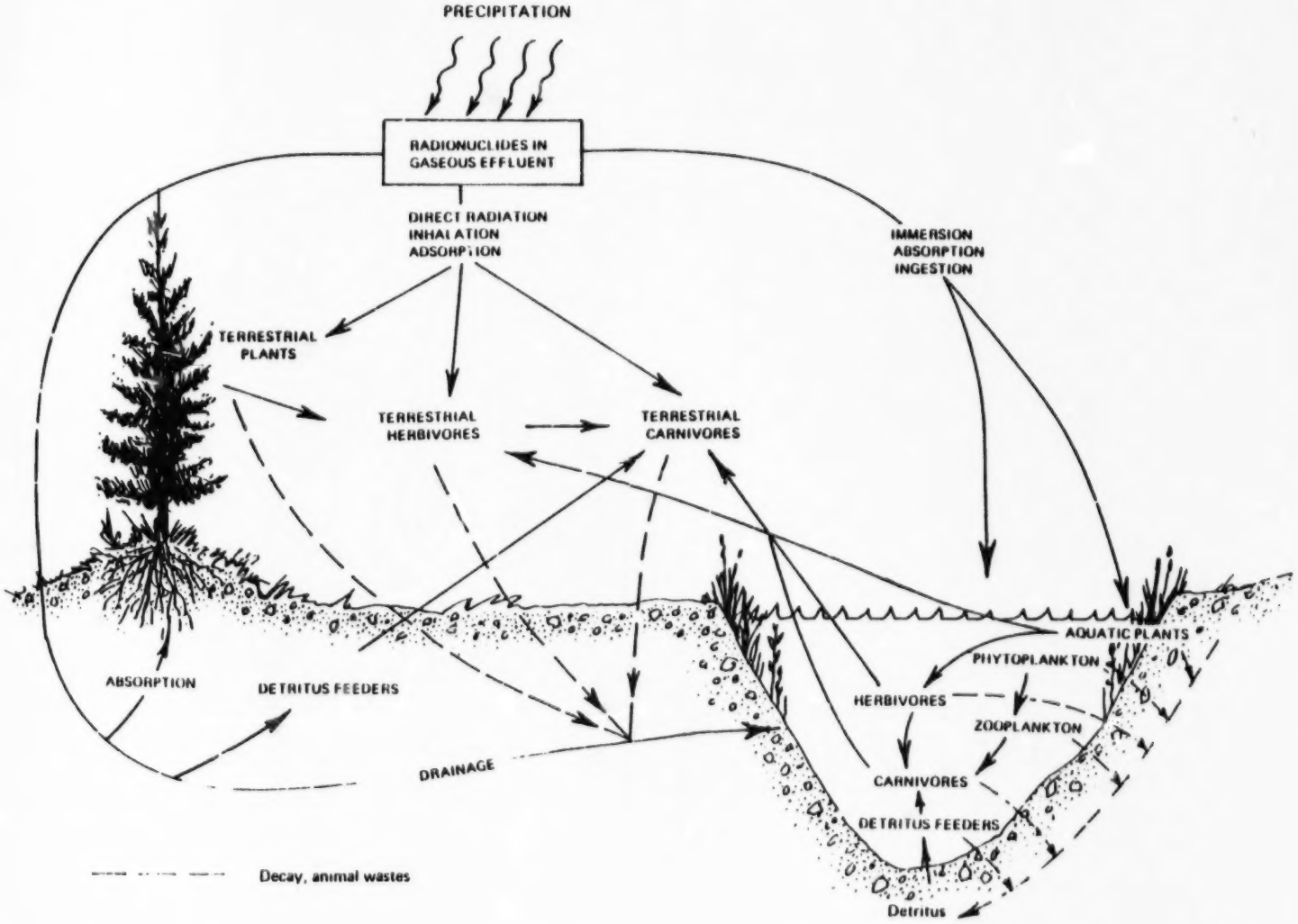

Figure 37. Illustration of transport pathways for radionuclides in aquatic and terrestrial environments.

between the biotic and abiotic compartments. The rates at which radionuclides are distributed throughout an ecosystem determine the speed with which their steady state distribution is reached and the final distribution patterns that are obtained.

The post-operational monitoring program for the Point Lepreau NGS emphasizes the early detection and monitoring of reactor-derived radionuclides, while continuing to stress an ecosystem approach to the understanding of radionuclide transport. During the initial stages of the reactor operation, activity levels in most biotic and abiotic phases are expected to remain at background levels. Table 2, section 2.2, gives the activities of radionuclides released by the reactor during 1983, but because of the rapid mixing of waters within the Bay of Fundy, none of the radionuclides released were measured except in the immediate vicinity of the reactor outfall. On the other hand, elevated tritium signals were observed at several of the air monitoring stations operated by AERU, pointing out the importance of selecting species which directly intercept atmospheric deposition for analysis. Emphasis during the initial year of post-operational activity has been placed on those biotic and abiotic compartments which have exhibited (in the pre-operational phase) properties that make them useful environmental monitors. Plant species, such as lichen, blueberry leaves and alder leaves and animal species such as muskrat and frogs have been sampled in 1983. Soil and fresh water sediments, which act as radionuclide sinks, are part of the long range sampling program and will be studied later in the operational program.

5.1 Aquatic Systems

The physical and chemical behavior of radionuclides in aquatic systems is very complex (Figure 37). The movement of pollutants through aquatic systems will, in general, be at low concentrations and may be influenced by the presence of other materials,both inorganic and organic, in the water. This includes dissolved ions, variations in pH, suspended particulate matter and silt and clay particles. Physical transport processes include currents, sedimentation, resuspension and turbulent and convective mixing. At the same time, chemical transport processes including absorption, adsorption, dissolution and ion exchange all effect the transport of radionuclides in aquatic systems. In general, the fate of radionuclides in aquatic systems has been studied using long-lived biologically important radionuclides such as Sr-90, and Cs-137. Tracy and Prantl (1983) found that, although bottom sediments acted as a sink for Cs-137, it was distributed throughout the ecosystem with concentration factors from 400 to 6000. In experiments involving artificially contaminated lakes, concentration factors for most radionuclides were found tc range over many orders of magnitude for biological materials and values from 100 to 25,000 have been reported in the literature (Polikarpov, 1966). The magnitude of the concentration factor varies depending on the radionuclide, the organism in question and even the ecosystem. Concentration factors for H-3 are generally less than one for most organisms (IAEA, 1981) while concentration factors of up to 300,000 have been measured for P-32 in algae (Kornberg and Davies, 1966). Commonly, lakes which are oligotrophic (low nutrient levels, comparatively high dissolved oxygen) are inhabited by organisims having higher radionuclide levels than those found in eutrophic lakes.

The five sampling sites, T-1 to T-5, selected for collecting aquatic samples are located as illustrated in Figure 38. Two of the sites (T-2 and T-4) are small lakes and the remaining sites are stream locations. The experimental methodology for the preparation of biological, sediment and water samples and subsequent analysis using nuclear instrumentation are similar to procedures discussed earlier in this report (section 4.2). The principal difference is that the analytical problems associated with the high salt content of marine samples are not encountered in freshwater samples.

5.1.1. Water Column Results

Fresh water samples were collected in September, 1985 at the five aquatic sampling sites indicated in Figure 38. Twenty ml samples were collected in glass vials for H-3 analysis; tritium exhibits no partitioning between dissolved and particulate phases, and 50 liter water samples were collected for the analysis of Cs-137, of which up to 90% can be found associated with sediment material (Coughtrey et al., 1983).

Cs-137 tends to follow particle pathways through aquatic systems and its overall distribution depends on the size and physico-chemical characteristics of the aquatic system (Smith and Ellis, 1984). Soluble Cs-137 activities measured in aquatic systems in the Point Lepreau area in 1983 ranged from 0.3 ±0.2 mBq/l to 2.7 ±0.5 mBq/l with an average of 0.9 ±1.0 mBq/l (Table 18). Particulate Cs-137 levels ranged from 0.8 to 1.8 Bq/l, (average 1.3 ±0.4 Bq/l) and the total Cs-137 activities measured ranged from 1.3 to 3.6 m Bq/l with an average value of 2.2 ±0.8 m Bq/l. Results from the pre-operational phase of the environmental monitoring program are similar where the soluble Cs-137 average was 1.6 ±1.1 m Bq/l, the

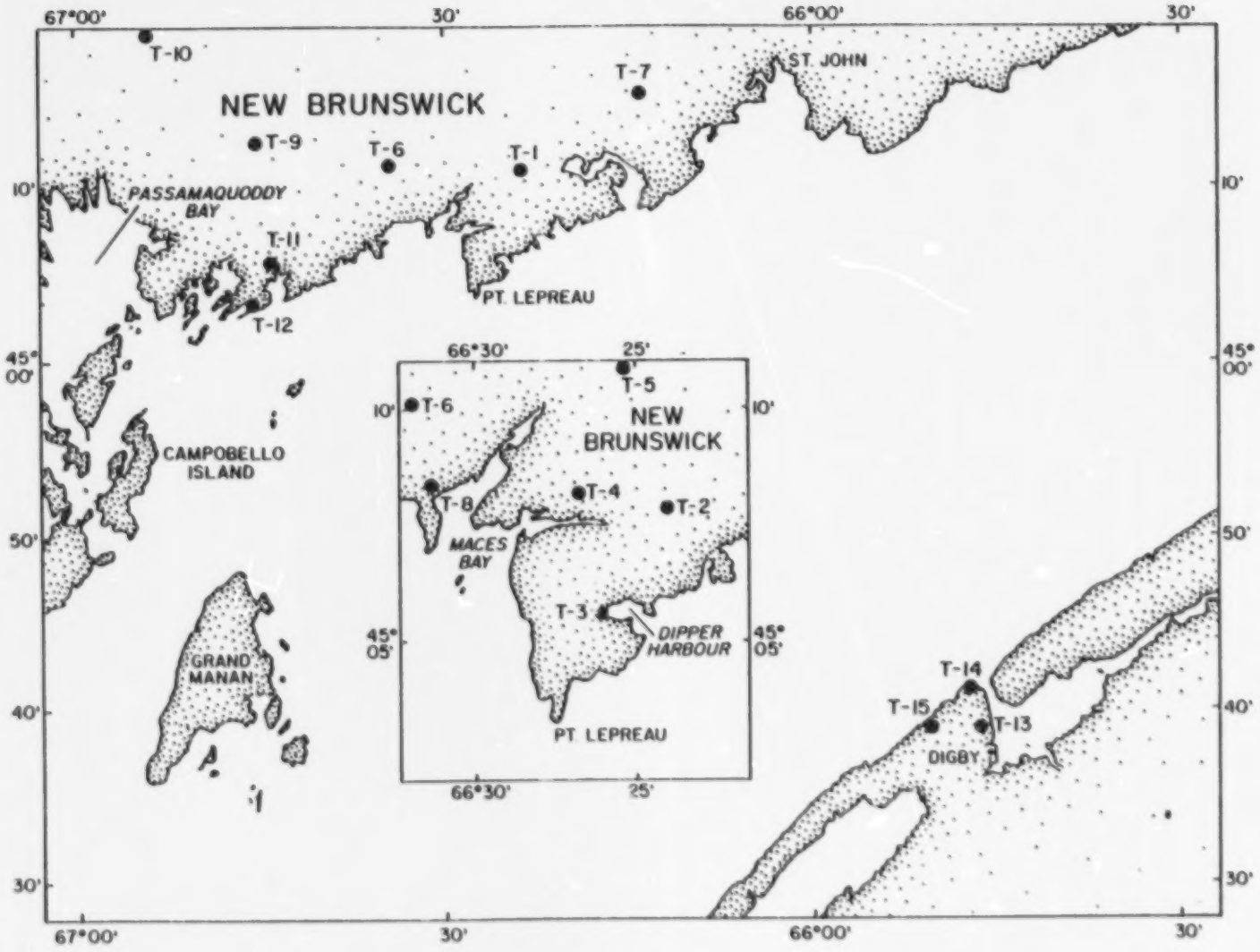

Figure 38. Aquatic and terrestrial sampling sites in the vicinity of Point Lepreau, N.B.

Table 18. Cs-137 and H-3 results for water and suspended particulate material from aquatic sites near Point Lepreau.

Sample No.	Sampling Site	RSPM Level mg/l	H-3 Bq/l	Cs-137 Soluble (mBq/l)	Particulate (mBq/l)	(Bq/g)	Total Cs-137 mBq/l	Distribution Coeff. Kd (Bq/g/Bq/ml)
1981-82	1	1.00	8.0 ± 2.6	1.0 ± 0.7	0.5 ± 0.7	0.5 ± 0.7	1.5 ± 2.2	0.5×10^6
	2	1.08	7.4 ± 4.5	2.0 ± 0.3	2.7 ± 0.5	2.9 ± 1.3	4.7 ± 0.7	1.4×10^6
	3	0.61	6.1 ± 0.1	<0.8	0.4 ± 0.6	0.7 ± 1.0	<1.2	0.8×10^6
	4	1.70	5.8 ± 0.6	<0.8	0.8 ± 1.4	0.5 ± 0.8	<1.6	0.6×10^6
	5	1.04	4.8 ± 0.4	3.3 ± 0.5	1.2 ± 1.0	1.3 ± 0.9	4.5 ± 3.8	0.3×10^6
1983								
83-9320	1	0.49	3.5 ± 2.0	0.5 ± 0.3	0.8 ± 0.1	1.6 ± 0.9	1.3	3.2×10^6
83-9321	2	0.42	3.5 ± 2.0	0.7 ± 0.3	1.4 ± 1.1	3.2 ± 2.9	2.1	4.6×10^6
83-9323	3	17.16	5.4 ± 2.0	2.7 ± 0.5	0.9 ± 0.5	0.06 ± 0.04	3.6	0.02×10^6
83-9325	4	16.56	2.7 ± 2.0	0.5 ± 0.5	1.8 ± 5.1	0.11 ± 0.10	2.3	0.22×10^6
83-9317	5	0.73	7.3 ± 2.0	0.3 ± 0.2	1.5 ± 0.1	2.0 ± 0.3	1.8	6.7×10^6

particulate average was 1.1 ±0.9 Bq/l and total Cs-137, 2.7 ±1.7 m Bq/l and indicate no change in Cs-137 inventories in the Point Lepreau watershed.

The Cs-137 concentration per gram found in particulate matter range from 0.06 to 3.2 Bq/q with an average value of 1.4 ±1.3 Bq/q. these values are similar to maximum activities found in surface soils in the vicinity of Point Lepreau of 0.1 Bq/q and in surface sediments of Retreat Lake northwest Point Lepreau of 0.7 Bq/q.

Approximately 75% of the Cs-137 is associated with particulate material, with the exception of site 3, where a high level of soluble Cs-137 was measured. the partitioning of a radionuclide between dissolved and particulate forms can be characterized by a distribution coefficient, which is identical to a concentration factor for suspended matter. Distribution coefficients ranged from 0.02×10^6 to 6.7×10^5 with an average value of $2.9 \times 10^6 \pm 2.8 \times 10^6$ (Table 18). These distribution coefficients are generally higher than those measured in 1981 but are still in the range typical of aquatic systems (Alberts and Wahlgren, 1981). Differences may be due to seasonal differences as 1981 samples were collected in July and 1983 samples in September.

Tritium results for the five aquatic sampling sites ranged from 2.7 to 7.3 Bq/l with an average value of 4.5 ±1.9 Bq/l. These values are comparable to pre-operational H-3 levels observed where in 1981 the mean tritium activity was 5.2 Bq/l and in 1982 was 7.5 Bq/l. There is no evidence of the enhanced tritium signal observed at the air monitoring stations as yet in aquatic systems around Point Lepreau. During the pre-operational program, aquatic tritium activities reflected levels of tritium found in atmospheric moisture. In 1981, the average fresh water tritium level of 5.2 ±1.2 Bq/l, was very close to the average tritium level in air

moisture of 5.9 ±3.8 Bq/l and in 1982 again the average tritium level 7.5 Bq/l found in water is within the range found for tritium in air 5.8 ±2.4 Bq/l. In 1983, the average tritium concentration in air moisture was 18 ±30 Bq/l compared to 4.5 ±1.9 Bq/l found in aquatic samples indicating that the watershed in the Pt. Lepreau area is large enough to dilute tritium which is being deposited in fresh water to background levels.

5.1.2 Aquatic Plants and Animals

The predominant mechanisms for the accumulation of radionuclides in aquatic plants and invertebrate animals are adsorption and absorption, generally leading to a more direct equilibration with air and water. Vertebrate animals, on the other hand, accumulate radionuclides mainly by ingestion, resulting in slower response times to environmental levels of radioactivity.

Radionuclide results for aquatic plants and animals collected near Point Lepreau and summaries for the major plant groups sampled during the pre-operational phase are presented in Table 19. During the initial year of the operational program, samples of Typha sp. (cattail) were collected and the levels of Cs-137 were below AERU detection limits.

Aquatic vertebrates sampled during 1983 include the fish species Cyprinidae cyprinidae and Pungitius pungitius and several frog species including Rana sylvatica and Rana catesbyiana. Radionuclide results for aquatic vertebrates sampled at sites located as shown in Figure 38 are given in Table 20. Cs-137 was the only radionuclide detected in the fish and the frog samples. The range in Cs-137 values found for fish species was <6 to 34 Bq/kg compared to pre-operational activities of 5 to 17 Bq/kg. The range in Cs-137 activities found for frogs sampled in the area was 15

Table 19. Radionuclide results for aquatic plants collected near Point Lepreau.

Species	Sample No.	Component	Collection Site	Collection Date	Sample Weight	Geometry	%H_2O	Cs-137 (Bq/kg)	Range
Horsetail *Equisetum sp.*	1981-82	Total	T-1, T-5	-	-	-	78.9	56 ± 80	< 2 to 230 ± 8
Wild Iris *Iris versicolor*	1981-82	Total	T-1, T-5	-	-	-	79.8	15 ± 20	3 ± 1 to 55 ± 7
Water Lily *Nuphar sp.*	1981	Total	T-1, T-5	-	-	-	90.5	52 ± 28	28 ± 6 to 85 ± 6
Cattail *Typha sp.*	1981	Total	T-3	13-7-81	23.6	1	88.0	< 13	
	83-9235	Head	T-3	30-9-83	58.62	1	64.2	< 1	
	83-9237	Leaves	T-3	30-9-83	35.63	1	73.5	< 2	
	83-9241	Head	T-4	30-9-83	66.47	1	58.8	< 1	

Table 20. Radionuclide results for aquatic vertebrates collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	%H_2O	Cs-137 (Bq/kg)	Cs-137 (C.F.)	Co-60 (Bq/kg)	Range (Cs-137)
Fish	1981	Total; n=3	T-1 to T-5	-	-	-	87.4	11.5	0.36-1.1x10^3	9.6	5±4 to 17±4
	83-9214	total	T-1	22-6-83	7.6	4	78.3	<18	<8x10^3	<19	-
	83-9216	total	T-2	22-6-83	15.94	3	70.8	17 ± 9	7x10^3	< 9	-
	83-9218	total	T-3	22-6-83	13.70	4	78.5	< 6	<5x10^2	< 7	-
	83-9220	total	T-4	22-6-83	16.36	3	77.7	<13	<6x10^3	<16	-
	83-9222	total	T-5	22-6-83	63.95	1	78.8	34 ± 3	2x10^4	< 1	-
Frog	1981	total; n=3	T-1 to T-5	-	-	-	81.3	35 ±12	2.5-3.7x10^3	10	24±3 to 49±9
	83-9215	total	T-1	22-6-83	25.40	3	79.7	15 ± 5	6x10^3	< 5	-
	83-9217	total	T-2	22-6-83	19.61	3	82.1	31 ±14	6x10^3	<15	-
	83-9219	total	T-3	22-6-83	2.30	5	79.8	95 ±20	7x10^3	<22	-
	83-9221	total	T-4	22-6-83	24.06	3	80.9	22 ±10	8x10^3	<11	-
	83-9223	total	T-5	22-6-83	21.22	3	81.1	32 ±10	2x10^4	<12	-

to 95 Bq/kg compared to pre-operational activities of 24 to 49 Bq/kg. Both the range of Cs-137 activities and the average activity (39 ±32 Bq/kg) found in frogs was much higher than that found for fish from the same fresh water sites (average Cs-137 activity = 18 ±10). In general, fish live in the water column where Cs-137 activities are lowest while frogs spend a significant portion of their time in sediments where Cs-137 activities are expected to be much higher. For example, the concentration of Cs-137 in surface sediments at Retreat lake (site T-2) has been measured to be as high as 0.7 Bq/g, while in 1983, the average dissolved Cs-137 in freshwater systems was 0.9 ±1.0 mBq/l. It is interesting to note that at the site with the highest soluble Cs-137 activity, the frog sample also had the highest Cs-137 activity for those samples analysed, but Cs-137 activity in the fish sample from the same site was below the AERU detection limit.

The range in concentration factors for fish samples collected in 1983 (see Table 20) was comparable both to those calculated in 1981 (1983 $<5 \times 10^2$ to 2×10^4; 1981 0.36×10^3 to 1×10^3) and of those calculated forwhole fish in Finnish lakes of 75 to 1×10^4 (Coughtrey et al., 1983). Accumulation of Cs-137 in freshwater fish is related to body weight, as well as a range of other variables including temperature, feeding habits, potassium concentration and turbidity of the water. The range in concentration factors for frog samples was similar to that found for fish (Table 20) indicating that negligible preferential uptake of Cs-137 occurs for one species compared to the other. The higher concentration factors found in aquatic vertebrates in 1983 compared to 1981 may be related to the lower soluble Cs-137 activites found in fresh water in 1983. Pre-operational fresh water soluble Cs-137 levels averaged 1.6 ±1.1 mBq/l while soluble Cs-137 found in samples collected in 1983 averaged 0.9 ±10 mBq/l while the

range of Cs-137 activities measured in aquatic vertebrates was only slightly higher.

The absorption, distribution and retention of Cs-137 differs widely between species, genera and animal groups as well as with a variety of physical factors. In general, Cs-137 is concentrated rapidly by aquatic organisms and equilibrium is achieved within a few days to a few weeks (Coughtrey et al., 1983). Concentration factors for freshwater organisms are higher than those for marine organisms and values are expected to vary from location to location.

5.2 Terrestrial Systems

Greater variability in radionuclide levels is generally observed in terrestrial compared to aquatic systems. The residence times of most radionuclides in air are much shorter than their residence times in water, and as a result, a steady state in radionuclide levels can be established throughout the different components of an aquatic system more rapidly and efficiently than throughout a terrestrial ecosystem. Physiography, microterrain and microclimate variables which control processes within the ecosystem and the properties of radionuclide transport within these systems are important factors governing the nature of terrestrial ecosystems. Biological uptake of fallout radionuclides is generally more efficient in the terrestrial environment, compared to aquatic and marine ecosystems, because of the absence of a diluting medium such as water. The end result is the accumulation of higher levels of fallout radionuclides in land-based plants and animals as illustrated in pre-operational data (Ellis et al., 1984).

5.2.1. Terrestrial Plants

Radionuclides are accumulated in plants by uptake from soils, atmospheric deposition and sorption from water. Dissolved radionuclides pass through root membranes and are subsequently incorporated into plant tissue. Radionuclides adsorbed onto plant surfaces may become incorporated into plant tissue through stomates or outer epidermal layers. In many plants, much of the radioactivity is simply adsorbed onto surface layers and can be removed by leaching (Takashima et al., 1978).

The selected plant species for monitoring at Point Lepreau for the initial year of the operational program include lichen and moss, which are both efficient collectors of atmospheric deposition, alder leaves, which are good indicators for water borne radionuclides and are typical of plants at the base of the food chain, and blueberry leaves.

Alder and blueberry leaves:

Alnus rugosa (speckled alder) is found predominantly in drainage areas and is considered to be a good indicator of water-borne radionuclides. Alder is at the base of the food chain and, although not a primary browse species, it is utilized by insects which in turn are consumed by amphibians, birds, mammals, and reptiles. Radionuclide results for alder samples collected at the terrestrial sampling sites, indicated in Figure 38, are presented in Table 21. Only Cs-137 was detected in the samples analysed and values ranged from <1 to 32 ±3 Bq/kg with an average value of 10 ±13 Bq/kg. Pre-operational Cs-137 activities found in alder leaves ranged from <2 to 35 ±2 Bq/kg with an average value of 22 ±13 Bq/kg. Pre-operational levels of blueberry leaves ranged from 14 ±2 to 253 ±7 Bq/kg with an average Cs-137 activity of 96 ±76 Bq/kg in 1981 and which decreased to 63 ±56 Bq/kg in 1982. Blueberry leaves collected during the initial

Table 21. Radionuclide results for terrestrial plant samples collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	$\%H_2O$	Cs-137 (Bq/kg)	Ce-144	Be-7	Range (cs-137)
Alder	1980	buds	T-1,2 3,4,5	-	-	-	-	21± 8	-	-	16±2 to 27±3
Alnus rugosa	1980	branches	T-1,2 3,5	-	-	-	-	4± 1	4.6± 1.0	-	3±2 to 6±2
	1982	leaves	T-1,2 3,4,5	-	-	-	59.1	22±13	-	68±11	<2 to 35±2
	83-9227	leaves	T-1	30-9-83	54.17	1	55.6	< 1			
	83-9233	leaves	T-3	30-9-83	61.96	1	52.8	7± 2			
	83-9230	leaves	T-2	30-9-83	55.86	1	57.2	10± 2			
	83-9239	leaves	T-4	30-9-83	79.54	1	56.1	< 2			
	83-9317	leaves	T-5	30-9-83	90.84	1	54.1	32± 3			
Blueberry	1981	leaves	T-1 to T-12	-	-	-	6.0*	96±76	113 ±44	108±33	15±3 to 253±7
	1982	leaves	T-1 to T-12	-	-	-	62.4	63±56	-	-	14±2 to 197±5
	83-9240	leaves	T-4	30-9-83	44.23	1	51.4	74± 9	-	-	
	83-9228	leaves	T-1	30-9-83	48.69	1	49.5	7± 2	-	-	
	83-9318	leaves	T-5	30-9-83	40.18	1	55.4	4± 2	-	-	
	83-9236	leaves	T-3	30-9-83	45.89	1	48.2	24± 3	-	-	
	83-9231	leaves	T-2	30-9-83*							
Grass	83-9319	total	T-5	30-9-83	79.93	1	40.3	<1			
	83-9234	total	T-3	30-9-83	44.45	1	63.7	<1			
	83-9238	total	T-4	30-9-83	19.24	1	51.1	<2			
	83-9239	total	T-2	30-9-83	43.27	1	59.6	<2			
	83-9229	total	T-1	30-9-83	48.75	1	44.2	<2			

* 1981 blueberry leaves received in semi-dry form.

year of the operational program contained cesium activities ranging from 4 ±2 to 74 ±9 Bq/kg with an average Cs-137 activity of 27 ±32 Bq/kg. The decrease in Cs-137 activity observed in terrestrial plant samples since 1981 indicates that there has been no major input of Cs-137 to the atmosphere since the 1980 Chinese nuclear weapons test and Cs-137 levels are being reduced by natural radioactive decay and physico-chemical processes such as leaching.

In 1983, several samples of grass were collected and analysed for gamma-emitting radionuclides, all of which were below AERU detection limits. Bunzl and Kracke (1984) analysed grass samples from a heath in Germany and found that Cs-137 activities were below their detection limits of 20 Bq/kg indicating that grasses are not major accumulators of Cs-137.

The Cs-137 results for blueberry and alder leaves show a wide inter-species variability for plants taken from the same sampling sites. Differences ranged from 7 Bq/kg at site T-1 to 74 Bq/kg at site T-4 with higher values found for the blueberry leaves. The inter-species variability of Cs-137 levels found at the same sampling sites is not uncommon. Similar observations have been made by Remmenga and Whicker (1967) who found that Cs-137 values were four to seven times higher in blueberry leaves than aspen leaves at sites 10 meters apart. The uptake of radionuclides by plant species depends on the degree of fallout entrapment, plant surface characteristics, age, and the physiological demand for the radionuclide or stable analogue and these factors are responsible for the wide inter- and intra- species variability in the uptake of radionuclides in most aquatic and terrestrial plants.

Lichen

Lichen communities have long been recognized as a basic reservoir of natural and artificial radionuclides. The accumulation of radionuclides in lichen is enhanced by several factors; the persistance of aerial parts (plants with persistent aerial parts contain 2-10 times greater amounts of fallout materials than seasonal plants Hanson, 1966), slow growth rate, long life span, high ratio of surface to mass and foliar absorption of nutrients. These morphological and physiological characteristics of lichen, which have evolved to enable these organisms to exist in environmental extremes, serve to make them an excellent indicator of contaminant fallout. Work by Hanson et al. (1966) has shown that lichen retain approximately 10% of the fallout deposition. Their value as fallout indicators around industrial installations is well documented and it is widely recognized that there is a qualitative and quantitative improvement in lichen flora and a decrease in pollutant content of thalli as distance increases from the source of contamination (Goyal and Seaward, 1981).

Lichen play a particularly prominent role in the arctic, where the lichen-reindeer/caribou-man food chain has been the subject of many radiological investigations. High levels of Cs-137 were detected in Alaska lichens in 1959, which was followed by the detection of high levels in caribou in 1960 (Hanson, 1966). By 1962, Hanson had measured elevated levels of Cs-137 in Alaskan Eskimos which were comparable to those detected in reindeer-herding Lapps from Northern Scandinavia. The reduced potassium intake that occurs when organisms utilize lichen (which has only 10 to 50 percent of the potassium concentration of higher plants) as their primary food source leads to a higher retention of Cs-137. As an example of this, caribou and reindeer which feed mainly on lichen contain up to a ten fold

higher concentration of Sr-90 and Cs-137 compared to other large herbivores such as moose, which occupy the same regions, but which prefer different foods (Holleman et al., 1971).

The uptake of radionuclides by lichen is complicated by environmental factors. The influence of habitat is very pronounced; lichens from pine forests contained 925 Bq/kg Cs-137 dry weight, from tundra 815 Bq/kg and from deciduous forest 740 Bq/kg (Kwapulinski et al., 1985). Hanson and Eberhardt (1971), found that Cs-137 content in lichens followed a seasonal cycle with maximum values in the summer and minimum values in mid winter. Work carried out by Kwapulinski et al. (1985), should that accumulation of Cs-137 by lichen was influenced by altitude and that the coefficient of accumulation rose with increasing altitude. The uptake of radionuclides in lichen follows the series Cs-137 > Sr-90 > Fe-55 > Co-60 and different lichen types accumulate radionuclides with varying degrees of effectiveness. For example Cs-137 uptake can be summarized as terricolous lichens > epilithic lichens > epiphytic lichens and for Sr-90 the order changes to epiphytic lichens > terricolous lichens > epilithic lichens, (Kwapulinski et al., 1985).

The radionuclide activities found in 1983 lichen samples collected at sites located in Figure 38 are presented in Table 22. The radionuclides Cs-137, Ce-144, Be-7 and K-40 were detected in the majority of samples analysed. In most cases, where these radionuclides were not detected, it was due to delays between sampling and analysis. Cs-137 levels ranged from 28 ±2 to 232 ±4 Bq/kg with an average value of 97 ±52 Bq/kg. Cs-137 was measured in two lichen species; for C. rangiferna, the range was 28 ±2 to 232 ±4 Bq/kg ($\bar{x}$ = 108 ±60 Bq/kg) and for C. arbuscula, the range was 33 to 156 Bq/kg, ($\bar{x}$ = 85 ±42 Bq/kg). The difference in Cs-137 content of the two

Table 22. Radionuclide results for lichen samples collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	$\%H_2O$	Cs-137 (Bq/kg)	Be-7	Ce-144	K-40
C. rangiferna	1980	Total n= 5	all	-	-	-	5.2	232	-	44	-
	1981	Total n=10	all	-	-	-	8.6	233	402	283	-
	1982	Total n=17	all	-	-		11.8	128	172	61	-
	83-9201	Total	T- 1	1-3-83	51.94	1	-	82± 3	-	71±25	75±19
	83-9204	Total	T- 2	21-6-83	70.48	1	7.0	88± 2	758± 30	27± 5	-
	83-9204	Total	T- 2	21-6-83	70.48	1	7.0	88± 3	780± 40	28± 7	-
	83-9205	Total	T-13	21-6-83	30.98	2	-	75± 4	-	-	155±39
	83-9207	Total	T- 3	21-6-83	39.48	2	7.2	92± 7	<11316	76±46	-
	83-9208	Total	T- 3	21-6-83	52.04	1	6.2	133± 4	-	-	-
	83-9209	Total	T- 3	21-6-83	63.51	1	6.4	136± 3	-	-	86±14
	83-9210	Total	T- 4	21-6-83	78.16	1	8.5	238± 4	832±338	-	-
	83-9210	Total	T- 4	21-6-83	78.16	1	8.5	225± 4	791±321	-	-
	83-9211	Total	T-15	21-6-83	80.58	1	18.6	28± 2	<165	-	-
C. arbuscula	1981	Total n= 1	T- 7	14-7-81	45.5	1	11.7	265±10	417± 50	393±55	-
	83-9202	Total	T- 1	30-4-83	67.09	1	10.0	66± 3	<492	30±16	-
	83-9203	Total	T-14	21-6-83	89.23	1	10.6	33± 1	-	16±10	57± 9
	83-9206	Total	T- 6	21-6-83	97.12	1	8.8	86± 3	952± 46	26± 6	-
	83-9212	Total	T- 1	5-3-83	50.15	1	-	57± 2	1416±136	43± 9	-
	83-9213	Total	T- 1	21-6-83	68.28	1	-	72± 2	205± 39	43± 6	-
	83-9327	Total	T- 1	25-11-83	50.92	1	-	156± 3	-	10± 6	92±16
	83-9328	Total	T- 1	26-10-83	89.08	1	-	123± 4	-	-	59±16

lichen species is not unusual. Kwapulinski et al. (1985) found differences of up to 96 Bq/kg (average) among lichen species they were studying. The range Cs-137 values in C. arbuscula is within the range of Cs-137 activities found for C. rangiferna and the difference between the two species is within the intra-species variability for the samples collected in 1983. The average Cs-137 activity of 97 Bq/kg represents a decrease of 26% from 1982 Cs-137 levels of 128 Bq/kg. This is mirrored by a decrease of 35% in Ce-144 levels from an average of 58 Bq/kg in 1982 to 38 Bq/kg in 1983. The levels of Be-7 in lichen measured for 1983 have increased from 402 Bq/kg in 1982 to 831 Bq/kg. This substantial increase in naturally-produced Be-7 may be related to the increase in rainfall 1983 compared to 1982 which led to a decrease in Be-7 in air as discussed in section 3.2.2.1. An increase in rainfall would increase the amount of Be-7 removed from the atmosphere resulting in an increase in the amount of Be-7 available to plants that intercept atmospheric deposition (e.g. lichen). Thus the high level of Be-7 found in lichen samples for 1983 is in good agreement with this hypothesis.

The linear relationship observed in previous years for Be-7 vs. Cs-137 in lichen is not present in the 1983 data. The presence of a higher average Be-7 activity and high individual activities (e.g. sample 83-9212 - Be-7 = activity 1416 Bq/kg) coupled with decreased inputs of Cs-137 from the atmosphere may be responsible for this phenomena.

The linear relationship of Cs-137 with Ce-144 (Figure 39) is repeated in the 1983 data. Cerium-144 ($t_{1/2}$ = 284d) and Cs-137 ($t_{1/2}$ = 30y) are two radionuclides consistently measured in lichen during the pre-operational phase of PLEMP and are present again during 1983 the first year of the operational program. The lower Cs-137 and Ce-144 activities found

in lichen samples for 1983 indicate that there has been no new input of these radionuclides to the lichen. Levels of both Cs-137 and Ce-144 in atmospheric particulates were below AERU detection limits and no major input of either isotope has taken place since the 1980 Chinese nuclear test. Radionuclides are removed from lichen by several processes, radioactive decay, removal by washout and physiological decay (characterized by the biological half life), and consumption as a food source.

The measured ratio of Ce-144/Cs-137 shown in Figure 39 for the years 1980-1983 is characterized as follows; in the summer before the October 1980 Chinese nuclear test, Ce-144 and Cs-137 were measured at an average ratio of 0.17 (Std.dev. δ = 0.03). Samples collected in the summer of 1981 had an average ratio of 1.4 (δ = 0.3) reflecting the recent enhanced input of Ce-144 with respect to Cs-137 from the nuclear test. The ratio was smaller than that expected strictly from atmospheric deposition suggesting that a reservoir of Cs-137 was present in lichen due to the long lifespan of lichen (Smith et al., 1982). Ratios measured for samples collected in 1982 have lower ratios (average ratio of 0.50, δ = 0.14). The decrease in ratio between 1981 and 1982 is that predicted by the radioactive decay of Ce-144 and Cs-137 for that time period so that neither Ce-144 nor Cs-137 are preferentially removed or retained by lichen over the time period of a year. The results of 1983 (average ratio of 0.52, δ = .27) is again that predicted by the radioactive decay of Ce-144 and Cs-137 and indicates that over a three year period there has been little preferential removal of Cs-137 with respect to Ce-144 in lichen.

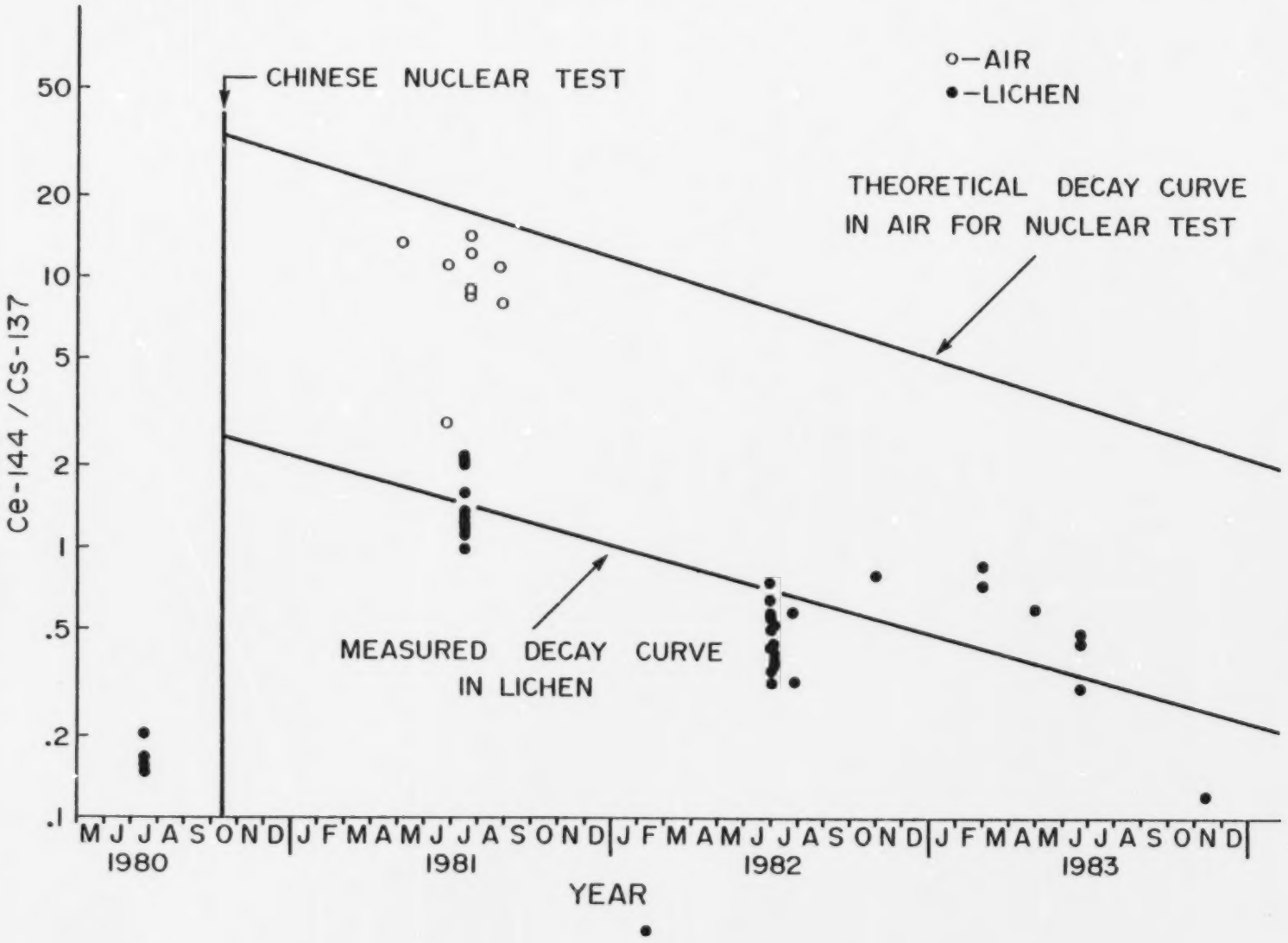

Figure 39. Measured isotopic ratio of Ce-144 / Cs-137 for air particulate material and lichen 1980- 1983.

5.2.2 Terrestrial Animals

The three principal herbivore species monitored for radioactivity at Point Lepreau are the muskrat (Ondatra zibethicus), varying hare (Lupus americanus), meadow vole (Microtus pennsylvanicus) and, when available, whitetailed deer (Odocoileus virginianus). During the first year of the operation program, only muskrats were sampled at sites T-3 and T-5. Muskrats feed on readily available emergent vegetation, cattail, water lily and other pond weeds as well as fresh water muscles and occasionally frogs and small turtles. During the pre-operational phase of the program only Cs-137 was detected in muskrats and activities were found to be highly variable. Results for 1983 are presented in Table 23 and again Cs-137 was the only radionuclide detected in these samples. Cs-137 activities in muscle ranged from <5 to 239 Bq/kg and it is interesting to note that the highest Cs-137 activities were found in the muskrat sampled at site #3 in Dipper Harbour where the highest Cs-137 activities were measured in frogs and where soluble Cs-137 activities were approximately an order of magnitude higher than at the other fresh water sites sampled. The concentration factor for Cs-137 in muskrat muscle (2×10^4) was similar to that found for fish and frogs. Cesium was also found in samples of brain, bone and liver of the same muskrats. The Cs-137 activity in muskrat liver of 101 ±9 Bq/kg was within the range for Cs-137 activities found during the pre-operational phase of the program (<3.0 to 108 ±5 Bq/kg). Cs-137 levels in both the bone (35 ±4 Bq/kg) and brain (60 ±22 Bq/kg) samples were higher than pre-operational levels but at levels less than found in the muscle or liver. Radionuclide results for muskrat samples collected during the initial year of the operational program emphasize the large variability in Cs-137 activities measured in muskrat samples during the entire sampling program.

Table 23. Radionuclide results for vertebrate animals collected near Point Lepreau

Sample	Sample No.	Component	Collection Site	Collection Date	Sample Wt (g)	Sample Geom.	$\%H_2O$	Cs-137 (Bq/kg)	Range
Muskrat	1980-82	Muscle	T-1 to T-5	-	-	-	73.6	44.0±68.0	1.9±0.7 to 173.0±15.0
Ondatra	1980-82	bone	T-1 to T-5	-	-	-	32.8	5.0± 2.0	<3.0 to 5.0± 2.0
Zibethicus	1980-82	liver	T-1 to T-5	-	-	-	70.8	60.0±45.0	<3.0 to 108.0± 5.0
	1980-82	brain	T-1 to T-5	-	-	-	74.4	< 5.0	-
	1982	stomach	T-1,T-5	-	-	-	78.9	3.8± 1.7	<2.0 to 3.8± 1.7
	83-9329	muscle	T-3	18-12-83	19.28	4	73.5	239±13	
	83-9333	muscle	T-5	18-12-83	18.96	4	74.0	< 5	
	83-9330,34	bone	T-3,5	18-12-83	28.63	4	47.1	35± 4	
	83-9331,35	liver	T-3,5	18-12-83	16.70	4	72.5	101± 9	
	83-9332,36	brain	T-3,5	18-12-83	2.00	5	77.7	60±22	

5.3 Tritium in Aquatic and Terrestrial Systems

The movement of tritium through ecological systems is complex and dependent on the medium in which the tritium is fixed. In general, the levels of tritium found in biological systems mirror tritium activities in the surrounding media, and concentration factors ranging from zero to slightly larger than one are the rule. Adams et al. (1979) reported that tritium levels in a contaminated freshwater marsh ecosystem generally followed marsh water tritium levels. Harrison et al. (1973) found that both cattails Typha angustifolia and filamentous algae Pithophora sp. grown in a contaminated pool reached tritium levels from 70 to 100% of the original pool water but no concentration effects were observed. Work done during the pre-operational phase of PLEMP served to reinforce these observations. Tritium levels measured for various plant and animal species all fell within the range of tritium levels measured in the various freshwater systems in the Point Lepreau region (Ellis et al., 1984). Table 24 presents the tritium levels found in 1983 and provides a comparison of pre-operational and operational tritium levels found in aquatic and terrestrial systems.

In the initial year of the operational program, three terrestrial plant samples were analyzed for tritium; a sample of cattail from site # 3 at Dipper Harbour, a sample of blueberry leaves from site T-4, and a sample of golden rod growing beside air monitoring station # 3 at the tip of Point Lepreau (Figure 40). Tritium results for plants samples analysed in 1982 and 1983 shown in Figure 40 can be compared to Figure 32 (Section 3.2.1) which gives the results for the air monitoring stations for 1982 and 1983. Tritium activities in plants for 1982 are similar to tritium activities measured in both the atmosphere (Figure 32) and fresh water (Table 18) in

Table 24. Comparison of tritium levels found in aquatic and terrestrial systems.

Species	Sample No.	Site No.	H-3 (Bq/l)	Concentration Factor
Pre-operational				
Water	-	-	7.5 ±2.5	-
Plants:				
Equisetum sp.	82-13357	T-4	4.5 ±1.6	0.6
Iris versicolor	82-13353	T-5	5.4 ±1.6	0.7
C. rangiferna	82-9951	T-1	3.6 ±2.2	0.5
Sphagnum sp.	82-13338	T-2	6.0 ±1.6	0.8
Alnus rugosa	82-13348	T-5	3.7 ±1.6	0.5
Vaccinium sp.	82-9953,54	T-10,12	4.2 ±1.3	0.6
Post-operational				
Water	-	T-1 to T-5	4.2 ±1.8	Range: 2.7 to 7.3
Plants:				
Vaccinium sp.	83-9240	T-4	7.5 ±1.8	1.8
Typha sp. (head)	83-9235	T-3	36.9 ±2.0	8.8
(leaves)	83-9237	T-3	17.3 ±1.8	4.1
Golden rod	83-9226	T-	14.2 ±2.0	3.4

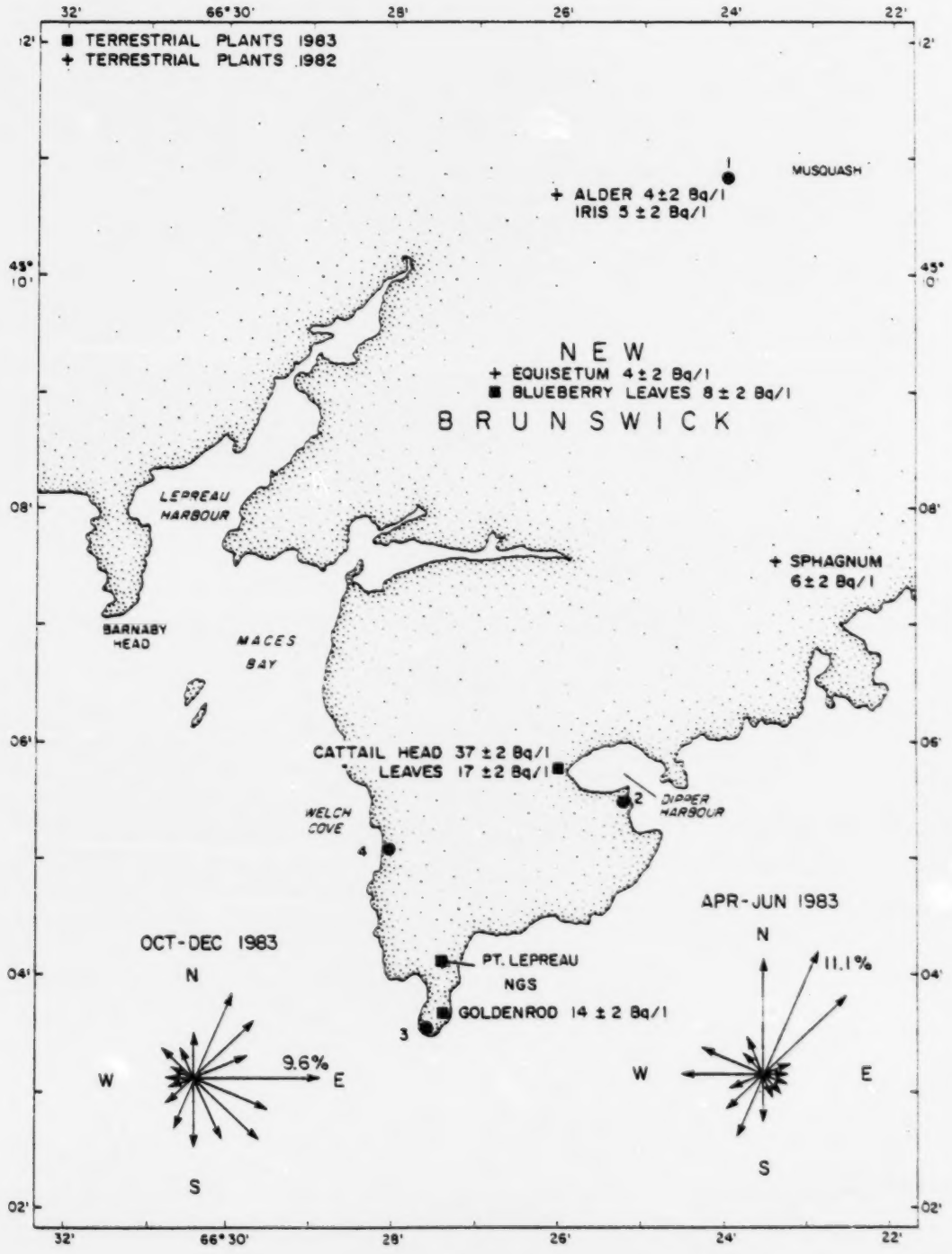

Figure 40. Tritium activities measured in plant samples in the Point Lepreau region, 1982 and 1983.

1982. Concentration factors calculated for terrestrial plants were all less than one and results mirror the constant background tritium signal that was observed during 1982. The Point Lepreau NGS became fully operational in 1983 (Table 1) and tritium activities measured at the air monitoring stations in 1983 clearly indicate an increase in tritium concentration over pre-operational levels, with the highest signal at the top of Point Lepreau and moving in a southwesterly direction, e.g. towards Dipper Harbour. The tritium signal observed at air monitoring station #1 (Figure 32) remains at pre-operational levels and the sample of blueberry leaves taken from the same area at T-4, 83-9240, has a tritium activity (8 ±2 Bq/l) only slightly higher than pre-operational levels. Tritium activities measured in the samples collected within the area in which increases in atmospheric tritium levels were observed were considerably higher; cattail heads from site T-3 contained tritium levels of 37 ±2 Bq/l, leaves from the same cattail plant, contained tritium levels of 17 ±2 Bq/l and golden rod from air monitoring site #1 had levels of 14 ±2 Bq/l. These tritium levels are directly related to the enhanced tritium signals observed at nearby air monitoring sites. At air monitoring station #2, located close to T-3, the maximum tritium signal observed was 24 ±2 Bq/l and at air monitoring station #3, the maximum tritium signal that was observed was 149 ±3 Bq/l. This is also reflected in the concentration factors calculated for terrestrial plants in 1983 which ranged from two to nine indicating that the major input of tritium in the region was from atmospheric deposition.

The results presented in Figures 32 and 40 indicate the presence of an enhanced tritium signal in the Point Lepreau region originating from the Point Lepreau NGS. The results from both the air monitoring program and plant samples analyzed suggest that the tritium plume is being transported

by the prevailing southwesterly winds in a northeasterly direction with a limited sphere of influence which does not extend as far as air monitoring station #1 or terrestrial sampling site T-4 (see Figure 32 and 40) located approximately 20 km north of the Point Lepreau NGS.

6.0 LABORATORY INTERCOMPARISON STUDY

The AERU laboratory participates in 'blind' laboratory intercomparison studies conducted under the auspices of the United States Environmental Protection Agency (EPA) to maintain a periodic check on the laboratory's analytical precision and accuracy in radionuclide analysis. Radionuclides of interest are analysed in a variety of sample matrices and counting geometries to ensure comprehensive coverage of all sample configurations analysed at AERU. The results of the program are published and distributed through the U.S. and Canada by the EPA.

The AERU results for the period 1979 to 1982 have been published previously in Smith et al. (1982) and Ellis et al. (1984). The AERU results for 1983 are listed in Table 25. AERU analytical results are generally within two standard deviations of the EPA reported value. Tritium in water, Cs-137 on air filters and I-131 in water are in good agreement with EPA values. Sr-90 analysis shows good accuracy and precision. Postal delays resulted in the late arrival of some of the samples of mixed gamma emitters in water samples. Consequently, the short-lived radionuclides had decayed to activities below our detection limit. The results of the EPA intercomparison program indicate that there have been no significant problems existing with experimental procedures used in the AERU laboratory during the past year.

Table 25. Results of AERU laboratory intercomparison experiments with the Environmental Protection Agency (Las Vegas, Nevada).

Sample Matrix	Collection Date	Nuclide	EPA Value		AERU Value		Grand Mean (All Labs)		2 SD (AERU Expt.)	2 SD (All Labs)	AERU/ EPA
Water	11/02/83	H-3	2560	pCi/l	2538	pCi/l	2534	pCi/l	92	273	0.99
Water	10/06/83	H-3	1529	pCi/l	1550	pCi/l	1552	pCi/l	10	202	1.01
Water	09/12/83	H-3	2383	pCi/l	2575	pCi/l	2366	pCi/l	47	247	1.08
Air filter	25/03/83	Cs-137	27	pCi/F	28	pCi/F	31	pCi/F	1	5	1.04
Air filter	26/08/83	Cs-137	15	pCi/F	17	pCi/F	19	pCi/F	1	4	1.13
Air filter	25/11/83	Cs-137	20	pCi/F	20	pCi/F	24	pCi/F	1	5	1.00
Water	01/04/83	I-131	27	pCi/l	26	pCi/l	27	pCi/l	2	5	0.96
Water	16/12/83	I-131	20	pCi/l	20	pCi/l	20	pCi/l	1	4	1.00
Water	07/01/83	Sr-90	17.2	pCi/l	18	pCi/l	17	pCi/l	1	2	1.06
Water	09/05/83	Sr-90	13.0	pCi/l	10	pCi/l	13	pCi/l	0	2	0.77
Water	06/05/83	Sr-90	37.7	pCi/l	39	pCi/l	37	pCi/l	0	5	1.03
Water	09/05/83	Cs-137	27	pCi/l	26	pCi/l	27	pCi/l	6	8	0.96
Water	03/06/83	Cs-137	26	pCi/l	27	pCi/l	28	pCi/l	5	10	1.04
Water	07/10/83	Cs-137	22	pCi/l	20	pCi/l	22	pCi/l	5	6	0.91
Water	09/05/83	Cs-134	33	pCi/l	26	pCi/l	31	pCi/l	6	8	0.79
Water	03/06/83	Cs-134	47	pCi/l	41	pCi/l	44	pCi/l	1	8	0.87
Water	07/10/83	Cs-134	15	pCi/l	11	pCi/l	15	pCi/l	2	6	0.73
Water	09/05/83	Co-60	30	pCi/l	28	pCi/l	31	pCi/l	1	8	0.92
Water	03/06/83	Co-60	13	pCi/l	16	pCi/l	14	pCi/l	2	4	1.21
Water	07/10/83	Co-60	19	pCi/l	19	pCi/l	19	pCi/l	2	4	1.00
Water	03/06/83	Zn-65	36	pCi/l	34	pCi/l	37	pCi/l	2	6	0.94
Water	07/10/83	Zn-65	40	pCi/l	42	pCi/l	40	pCi/l	9	6	1.05
Water	03/06/83	Ru-106	40	pCi/l	39	pCi/l	40	pCi/l	33	14	.98

7.0 CONCLUSIONS

1. The year 1983 marks the first year of operation of the Point Lepreau Nuclear Generating Station and the first year of the post-operational monitoring program for PLEMP. The reactor reached criticality on July 25, 1982, was operating at 85% full power in January 1983 and has been generally operating at 100% full power since March of 1983. The major emphasis of the monitoring program was placed on the thermal plume produced as a result of the discharge of waste heat to the Bay of Fundy, H-3 levels at the reactor outfall and in atmospheric samples, and radionuclide levels in lichen.

2. Data from NBEPC's liquid effluent monitoring program (LEM) was used to calculate expected levels of radionuclides released at the cooling water outfall. These calculated levels were below AERU detection limits.

3. Levels of tritium in the Bay of Fundy ranged from <1.3 to 3.4 ±1.6 Bq/l ($\bar{x}$ = 2.5 ±0.9 Bq/l) and exhibit no seasonal or geographical anomalies. The mean Cs-137 activity in sea water for all stations was 3.29 ±0.58 m Bq/l with a range of 2.45 to 4.76 m Bq/l. No strong correlation between Cs-137 and other parameters, such as depth, salinity, or geographical location was observed. There was no evidence for increased tritium or Cs-137 activity in the Bay of Fundy due to the operation of the Point Lepreau NGS with the exception of tritium during the reactor release experiment.

4. There were no enhanced levels of radionuclides detected in marine sediments sampled in the Point Lepreau area.

5. The thermal plume study in May 1983 indicated that the thermal plume is trapped at intermediate water depths (≈ 8 m) due to the stratification of the water column caused by spring runoff. This was not anticipated in the original EIS. The maximum temperature increase observed was 3°C, higher than previously predicted and was a direct consequence of the stratification observed. The entrapment of the thermal plume at mid-water depths may result in reduced dilution and enhanced vertical transport of heat and radioactivity and greater impingement on the coastal enviroment.

6. A second thermal plume study was conducted in September of 1983 and the results were in good agreement with EIS predictions. The thermal plume was evident only at the surface and the maximum temperature increase observed was 2°C. The area of influence of the thermal plume was confined to approximately 1 km^2.

7. During the course of the September thermal plume study, controlled liquid waste releases were undertaken by the generating station releasing tritium at activities ranging from 42 to 508 Bq/l. A discrepancy between the levels of tritium reported to be released and those observed in the Bay of Fundy was observed. The reason for this is under investigation.

8. Results for tritium in air showed a major increase in tritium activities at air monitoring stations 2 and 3. A peak tritium activity of 149 Bq/l (compared to pre-operational baseline levels of 6 Bq/l) was observed. Enhanced tritium levels at the air monitoring station at Dipper Harbour compared to Welch's Cove indicate that the prevailing southwest winds in the area have a pronounced

effect on the direction of tritium releases in the atmosphere. The average tritium activity in air moisture of 5.8 Bq/l found during the pre-operational program increased to 18 Bq/l in 1983. AERU results compared favourably with results from NBEPC air monitoring stations located at the same sites.

9. Levels of fallout radionuclides in air particulate material were below AERU detection limits for 1983 and as expected, no increase in Cs-137 levels were found due to the operation of the NGS.

10. Levels of radionuclides found in marine systems showed no increase over pre-operational levels with the exception of tritium levels measured in algae samples collected at the cooling water outfall. These two algae samples showed an approximate two-fold increase in tritium activity over algae samples analysed during the pre-operational program.

11. Tritium levels measured in shell material in marine crustacea again showed an enhanced tritium signal similar to results found in 1982. The reasons for this are under investigation.

12. No increase in tritium or Cs-137 was detected in aquatic systems indicating that any influence of tritium or Cs-137 released from the NGS is readily diluted in the watershed of the Point Lepreau area.

13. Levels of radionuclides measured in aquatic and terrestrial animal and plant samples show no evidence of an increase over pre-operational levels. A decrease in the Cs-137 signal in terrestrial plants (lichen, blueberry leaves) indicates that there has been no recent major input of radionuclides to the atmosphere since earlier Chinese nuclear weapons explosions.

14. Tritium levels measured in terrestrial plant samples are higher for those samples collected close to the NGS. Results coordinate well with atmospheric increases in the tritium signal and support evidence of the importance of the southwesterly wind direction to the transport of stack gases from the NGS.

ACKNOWLEDGEMENTS

The working group on Point Lepreau Environmental Monitoring is composed of scientists from different government departments, (Appendix 1) all of whom have contributed to the development of this program. In particular, we wish to thank Gary Bugden (Bedford Institute of Oceanography) who supervised the physical oceanographic component of this program and E. Brandon and B. Taylor (Atmospheric Environmental Service, Bedford, N.S.) who supervised the meteorological aspects of PLEMP. Equally helpful have been Dr. D. Scarratt and L. Linkletter (Fisheries Biological Station, St. Andrew's, N.B.) who have guided much of the marine biological work; K. Brown, W. Sexsmith and K. Hughes, (Environment New Brunswick, Fredericton, N.B.) who have supervised much of the terrestrial and aquatic sampling, and B. Johnson (Canadian Wildlife Service, Sackville, N.B.) who supervised the bird sampling. In addition, Mia Huh, J. Abriel, Marie Svenson, Dr. David Assinder and Song Shulin have provided substantial analytical support in the AERU laboratory analysing samples for Pb-210, Cs-137, Pu and H-3 and Dr. J.M. Bewers, (Bedford Institute of Oceanography) has provided continual support and many helpful discussions throughout all stages of this program.

Residents of Point Lepreau, N.B. who have provided great assistance in the operation of the air monitoring stations include Mr. and Mrs. G. Thompson (Dipper Harbour), Mrs. J. Pollock (Musquash) and Mr. R. Mawhinney (Welch Cove) while Mr. M. Durkee has kindly provided similar support in the operation of an air monitoring station at Digby, N.S. Appreciation is also extended to those members of the N.B. Electric Power Commission's Health Physics Department who helped with the deployment and operation of air monitoring station equipment, notably Dr. J. Paciga, Mr. C. Nasin and Mr. J.B. McCulley.

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Appendix 1

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Appendix 2

Conversion factors for different radioactivity units.

1 Becquerel (Bq)	= 2.7×10^{-11} Curies (Ci)
1 Bq	= 27 pCi
1 Bq	= 60 dpm
1 Bq/l	= 8.3 Tritium units (TU)
1 Ci	= 3.7×10^{10} Bq
1 mCi	= 3.7×10^{7} Bq
1 pCi	= 3.7×10^{-2} Bq
1 dpm	= 0.0167 Bq
1 dpm	= 0.45 pCi
1 TU	= 0.12 Bq/l
1 TU	= 7.2 dpm/l
1 TU	= 3.2 pCi/l

Appendix 3

Detection limits (Bq/kg) for each radionuclide and geometry assuming a counting time of 10^5 s for analyses performed one month subsequent to sample collection. Detection limit for specific sample is determined by choosing detection limit for a radionuclide for the appropriate geometry and dividing by the sample weight. These estimates are approximate and will vary depending upon the specific counting times and delay between sample collection and analysis.

Nuclide	Half-life	Geometry 1	Geometry 2	Geometry 3	Geometry 4	Geometry 5
Ag-110 m	253 d	150	94	95	95	47
Ba-140	12.8 d	1700	1700	1000	1000	490
Be-7	53.6 d	1100	1200	690	670	370
Ce-141	32.4 d	280	330	170	140	110
Ce-144	284 d	780	900	460	400	200
Co-56	77 d	130	140	90	90	40
Co-57	270 d	110	130	63	54	35
Co-58	71 d	130	140	77	78	39
Co-60	5.26 y	120	120	65	69	35
Cr-51	28 d	1700	1800	1100	1001	570
Cs-134	2.07 y	110	120	69	69	33
Cs-137	30.2 y	107	100	62	60	31
Eu-152	12.5 y	660	690	410	410	200
Eu-155	1.81 y	300	340	160	160	69
Fe-59	44.6 d	340	330	190	200	89
I-131	8.06 d	1200	1400	780	750	410
La-140	40.2 h	510	510	340	360	190
Mn-54	313 d	110	110	67	65	31
Nb-95	35.1 d	180	180	110	110	54
Ru-103	39.6 d	150	160	93	92	46
Ru-106	1.0 y	900	940	540	550	250
Sb-124	60.2 d	18	20	11	11	6
Sb-125	2.7 y	240	260	150	147	73
Zn-65	244 d	290	260	140	150	73
Zr-95	64 d	240	240	150	150	70

Appendix 4

Detection limits (Bq/kg) for each radionuclide and geometry assuming a counting time of 10^5 s for analyses performed one year subsequent to sample collection.

Nuclide	Half-life	Geometry 1	Geometry 2	Geometry 3	Geometry 4	Geometry 5
Ag-110 m	253 d	380	410	240	240	120
Ba-140	12.8 d	-	-	-	-	-
Be-7	53.6 d	-	-	-	-	-
Ce-141	32.4 d	-	-	-	-	-
Ce-144	284 d	1700	2000	1000	890	660
Co-56	77 d	2600	2800	1600	1600	750
Co-57	270 d	250	300	150	140	82
Co-58	71 d	3400	3400	1900	1900	980
Co-60	5.26 y	130	130	74	78	40
Cr-51	28 d	-	-	-	-	-
Cs-134	2.07 y	150	160	93	940	45
Cs-137	30.2 y	110	110	63	61	32
Eu-152	12.5 y	700	720	440	430	200
Eu-155	1.81 y	420	480	220	230	98
Fe-59	44.6 d	57000	56000	32000	30000	15000
I-131	8.06 d	-	-	-	-	-
La-140	40.2 h	-	-	-	-	-
Mn-54	313 d	230	230	140	135	65
Nb-95	35.1 d	-	-	-	-	-
Ru-103	39.6 d	49000	53000	31000	30000	15000
Ru-106	1.0 y	1700	1800	1000	1000	470
Sb-124	60.2 d	800	880	500	490	250
Sb-125	2.7 y	300	330	180	180	91
Zn-65	244 d	730	680	370	383	190
Zr-95	64 d	7900	8200	4900	4900	2400